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Guest editorial: celebrating the 70th birthday of Hisham K. El-Hennawy – Egypt's arachnologist

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Introduction

Arachnology in the Middle East was, for centuries, shaped largely by colonial researchers. This was particularly evident in Egypt, which endured many decades of colonial rule. Today, Egypt has a number of active arachnologists, but since the 1980s local arachnology has been pioneered by a single man: Hisham K. El-Hennawy. Now, on the occasion of his 70th birthday, I am delighted to present this editorial, recognising the many contributions he has made to arachnology, spanning from over one hundred faunistic papers on arachnids to translations of major historical works, and establishing and editing the Middle East's only arachnological journal, which has now been running for over 30 years.

Biography

Hisham Kamal El-Din Mohamed El-Hennawy was born in El-Mansourah, El-Dakahlia, Egypt on 19th December 1955. After a happy childhood, a grown Hisham married his beloved wife Rana and in 1978 joined the Egyptian Ministry of Interior as a law enforcement officer. He would spend his entire police career at the Ministry of Interior, specialising in detection and interception of forged money and documents but also with training (some as a United Nations fellow) in detection of narcotics and computer forensics. At the time of his retirement in 2000, Hisham had become the Director of Egypt's Department of Documents' Examination and held the rank of Colonel, the third most senior rank possible in Egyptian law enforcement. During his time as a senior officer, Hisham also lectured on forensics of forgery and general criminology both

across Egypt and much wider to other parts of the Middle East and Africa. He also conducted classified missions in Iraq and Saudi Arabia during his tenure. During all this time, he was publishing on arachnids and editing *Serket*, the Middle East's only arachnological academic journal, in his spare time. Following his retirement, Hisham dedicated his life full-time to arachnology over the last 25 years.

Contributions to Arachnology

Hisham has attended many conferences on arachnology and zoology across the world, spanning as diverse a list of nations as Belgium, Egypt, Greece, India, Jordan, Panama, South Africa, Spain, and Switzerland (see Figs 1–3). It is no surprise that he has contributed significantly to numerous national and regional workshops, seminars, and symposia within Egypt. However, he also presented papers, posters, and delivered keynote lectures abroad in some of the aforementioned countries. Since 1979, he has been involved with the International Society of Arachnology (ISA) as the correspondent for Egypt and also been a member of the British Arachnological Society (UK), Australasian Arachnological Society (Australia), Egyptian Entomological Society, and The Zoological Society of Egypt, all since 1980. His memberships further include The Spider Club of Southern Africa (South Africa) since 1982, the American Arachnological Society (USA) since 1985, Groupe d'Etude des Arachnides (France) since 1991, and The Egyptian British Biological Society since 1996. Hisham is also part of the European Society of Arachnology (France) since 2000, the Egyptian Society of Natural Toxins (Egypt) from 2003 and the Egyptian Society of Biological Sciences since 2011, showcasing a clear, sustained, commitment to arachnology and related biological sciences across multiple regions.

In terms of fieldwork, Hisham has extensively worked across Egypt, and also many parts of Jordan, where his wife's family lives. Subsequently, the vast majority of new faunistic data on spiders of these countries has been published by Hisham (see below). His decades of fieldwork, particularly in Egypt, have enabled him to understand the indigenous arachnofauna better than anyone else, and he is presently working with colleagues to update the national checklist of Egyptian Araneae, which he originally established in the 1990s. During this time, he also translated into English, edited, and published a reprint of Audouin's 1825 work *Description de l'Égypte. Explication Sommaire des Planches d'Arachnides de l'Égypte et de la Syrie* published across issues of *Serket* in 1993.

100% of names for spiders described by Hisham are valid (see World Spider Catalog, 2025): *Adonea algerica* (El-Hennawy, 2004) (Eresidae), *Cheiracanthium siwi* El-Hennawy, 2001 (Cheiracanthiidae), *Hersiliola eltigani* El-Hennawy, 2010 (Hersiliidae), *Loureedia jerbae* (El-Hennawy, 2005) (Eresidae), *Ninetis toliara* Huber & El-Hennawy, 2007, *Nita* Huber & El-Hennawy, 2007 (Pholcidae), and *Nita elsaff* Huber & El-Hennawy, 2007 (Pholcidae, type species of *Nita*).

Hisham is also coauthor of four scorpion names: *Androctonus tibesti* Lourenço & El-Hennawy, 2022, *Androctonus minaeus* Abu Afifeh, Al-Saraireh & El-Hennawy, 2025, *Leiurus sahelicus* Lourenço, El-Hennawy & Ythier, 2025, and *Leiurus aegyptiacus* Lourenço & El-Hennawy, 2021 all of which are valid [the lattermost name was proposed as a junior synonym of *Leiurus libycus* (Birula, 1908) by Yağmur *et al.* (2025) but revalidated by Lourenço *et al.* (2025)].

Three arachnid names honour Hisham El-Hennawy: *Buthus elhennawyi* Lourenço, 2005 (Scorpiones: Buthidae), *Eresus elhennawyi* Řezáč, Vaněk & Střeštík, 2023

(Araneae: Eresidae), and *Oedignatha elhennawyi* Sherwood, 2023 (Araneae: Liocranidae).

Hisham has been a peer reviewer for 41 journals, spanning most zoological periodicals in the Middle East to arachnological journals from Europe, the Americas, and Africa. Hisham has also edited textbooks such as one on Biological Terminology by his late father Kamal (Egyptian politician and former vice-president of the National Assembly), a book on Egyptian arachnids in 2002 and one specifically on spiders in 2016, various general wildlife books translated into Arabic, and a variety of books on Egyptology (including reading hieroglyphics). Photography is another passion of Hisham's and his photographs of both vertebrates and invertebrates have been exhibited throughout Europe and the Middle East, as well as online collections.

Perhaps the most enduring contribution Hisham has made to arachnology was establishing *Serket* (the Arachnological Bulletin of the Middle East and Northern Africa), named after the Egyptian scorpion goddess and a corresponding namesake scorpion that Hisham owned (Fig. 4). *Serket* is now in its 21st volume, has published hundreds of papers, by over 120 authors from around the world. The journal is an important avenue for Middle Eastern arachnologists as Hisham publishes it at his own expense and does not charge open access fees to authors, and this is especially helpful to those publishing faunistic papers, as this field is critically underappreciated by many other journals. Over the course of 38 years, the journal has produced 21 volumes, comprising 78 parts, 4,435 pages, and 519 papers. These contributions were authored by 383 researchers from 32 countries, including: 1 author each from Austria, Azerbaijan, Canada, Denmark, Israel, Kazakhstan, Kenya, Russia, and Syria; 2 authors each from Bulgaria, China, Italy, and Japan; 3 authors each from Bangladesh, Belgium, Germany, Saudi Arabia, and South Africa; 4 from Cyprus, Jordan, and the U.S.A.; 6 from the Czech Republic, France, and Libya; 8 from Morocco; 9 from the U.K. [including the author]; 13 from Iraq; 14 from Iran; 52 from Algeria; 58 from Egypt; 83 from Türkiye; and 93 from India.

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Appendix

After learning that I was working on this editorial, several colleagues wanted to share the ways Hisham has impacted their careers for an appendix. I have attached their messages below:

Tarık Danışman (Türkiye): "*Hisham published the Serket journal on his own for many years and never gave up on it. He always treated us in a fatherly manner and took the utmost care to ensure that nothing went wrong in our work. We have learned and will continue to learn a lot from him.*".

Lynda Beladjal and Robert Bosmans (Belgium): "*... we are currently collaborating with our friend Hisham El Hennawy to compile a catalogue of the spiders of Egypt. ... Bosmans has already published two articles on the Linyphiidae, and the cooperation has been both collegial and enjoyable, as is also the case with the ongoing work on the Egyptian catalogue. Hisham is always willing to assist and responds promptly to all communication.*".

Andrew Smith (United Kingdom): "*Hisham came to my attention 37 years ago by the way of the British Arachnological Society, with a notice about the publication of Serket. I promptly wrote to him about Chaetopelma, and he kindly replied with oodles of information ... including some fascinating Egyptian folklore, all of which was used in the Baboon Spider publication. Our friendship has continued over the decades, borne by my admiration of the Herculean task that Hisham set himself – establishing a journal and catalogue for describing arachnids of the Middle East. The Chaetopelma section of my book would have been indeed a sorry shadow of itself without his input. Hassam, Happy Birthday, and Kol Sana Wenta Bekhair.*".

Fig. 1. Hisham at the 25th European Congress of Arachnology, 1995 in Geneva, Switzerland, left to right: Hisham, Bruno Condé, John L. Cloudsley-Thompson, and Christa Deeleman-Reinhold.

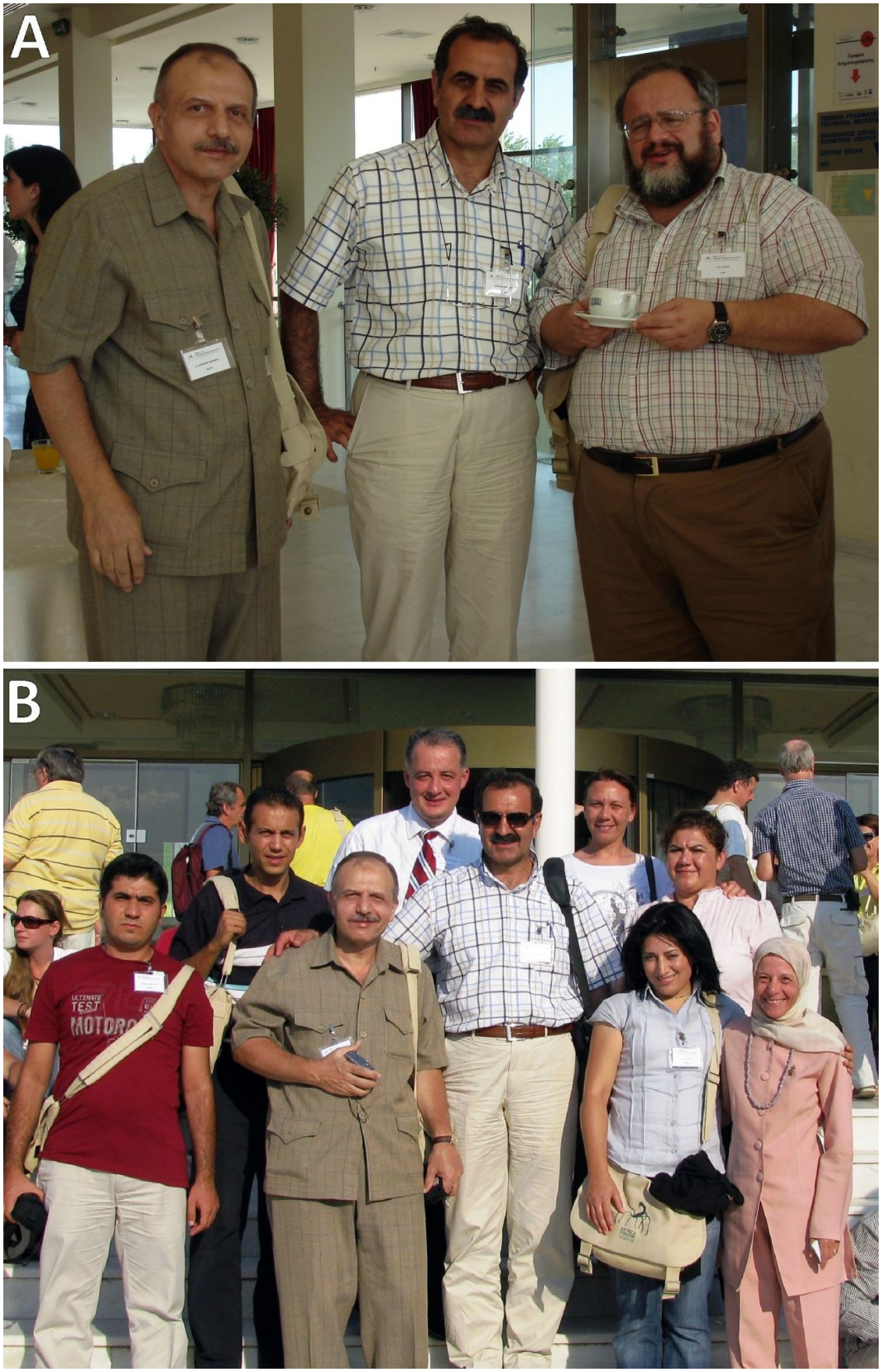

Fig. 2. Hisham at the 25th European Congress of Arachnology, 2009 in Alexandroupolis, Greece with other arachnologists. A. Hisham (left) with Abdullah Bayram (centre) and Victor Fet (right). B. left to right: Ersen Yağmur, Tarık Danışman, Hisham El-Hennawy, Abdullah Melekoğlu, Abdullah Bayram, Arife Yiğit, Rahşen Kaya, Nazife Yiğit, and Rana Qumei-El-Hennawy. Photographs courtesy of Tarık Danışman.

Fig. 3. Hisham at the 3rd Conference of Asian Society of Arachnology, 2015 in Amravati, India with other arachnologists. A. final forum, left to right: Ganesh Vankhede, Hisham El-Hennawy, Ingi Agnarsson, Matjaž Kuntner, Peter Jäger, Yuri Marusik, and Hirotsugu Ono. B. Hisham between Ganesh to the left and Rana to the right in the first row of conference participants photo.

Fig. 4. Hisham & *Serket*.

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Redescription of the female of *Egaenus turcicus* Snegovaya & Marusik, 2012 (Opiliones: Phalangiidae) with ovipositor morphology in Türkiye

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Abstract

The female of *Egaenus turcicus*, a harvestman species endemic to Türkiye, is redescribed based on newly collected material from Türkiye. Detailed images of the dorsal habitus, chelicera, pedipalp, and first pair of legs of the species are provided. In addition, the ovipositor morphology is photographed and described for the first time.

Keywords: Opiliones, *Egaenus turcicus*, ovipositor, redescription, Türkiye.

Introduction

Genus *Egaenus* C.L. Koch, 1839 belongs to family Phalangiidae and is represented by 14 extant species. These species are: *Egaenus amanensis* (Simon, 1884), *E. bajsun* Staręga & Snegovaya, 2008, *E. charitonovi* Gritsenko, 1972, *E. convexus* (C.L. Koch, 1835), *E. diadema* Simon, 1885, *E. kashmiricus* Caporiacco, 1935, *E. laevipes* (Caporiacco, 1935), *E. lindbergi* (Roewer, 1960), *E. oedipus* (Thorell, 1876), *E. pakistanus* (Roewer, 1956), *E. robustus* (Kulczyński, 1901), *E. turcicus* Snegovaya & Marusik, 2012, *E. turkmenicus* Chemeris & Snegovaya, 2010, and *E. zichyi* Kulczyński, 1901. Three of these species are known from Türkiye: *E. amanensis*, *E. convexus*, and *E. turcicus* (Kurt *et al*., 2010; Snegovaya & Marusik, 2012; Kurt, 2014; Kury *et al*., 2024a, 2024b).

Egaenus turcicus was originally described by Snegovaya & Marusik (2012) from the province of Bursa, Türkiye. A thorough description of the male specimens was provided, along with a concise overview of the female specimens. The structure of the ovipositor in the female was not specified, and no images were provided.

This study aims to provide a detailed redescription of the female *Egaenus turcicus* and to present the first illustration of its ovipositor.

Material and Methods

The specimens used in this study were collected from grass using pitfall traps and by hand. Images were taken using an LC20 camera mounted on an Olympus SZ61 microscope. These images were then combined using Combine ZM and edited using Adobe Photoshop CS3 software. Examined samples were preserved in 70% ethanol and stored in the author's personal laboratory. The ovipositor was cleaned by soaking them in a solution of 5% potassium hydroxide (KOH) for several hours (Wijnhoven *et al*., 2022; Kurt, 2024). Images of the ovipositor were then taken under a Leica ICC50 W microscope. All measurements are given in millimetres (mm).

Results

Family **Phalangiidae** Latreille, 1802

Genus ***Egaenus*** C.L. Koch, 1839

Egaenus turcicus Snegovaya & Marusik, 2012

Figs. 1-2; Map. 1

Material examined: Türkiye, Erzincan Province, Kavakyolu Town, 39°46'16"N, 39°27'09"E, 1149 m a.s.l., 10.VI.2023, 1♂ & 2♀♀, *leg*. M. Elverici.

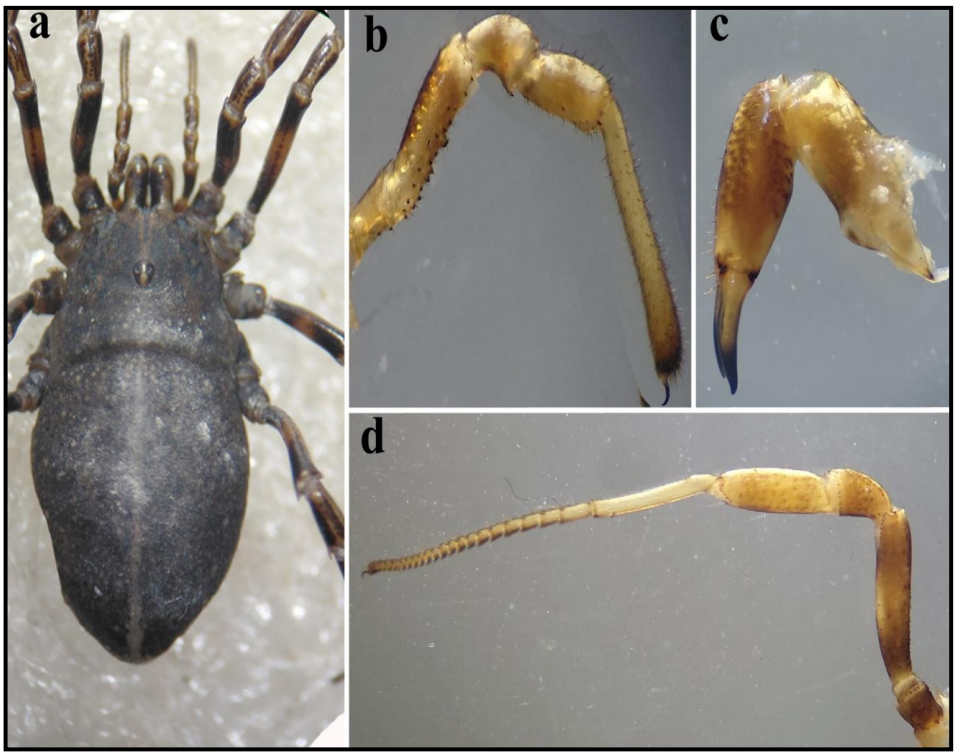


Fig.1. *Egaenus turcicus*, female, Türkiye. a. Body, dorsal view. b. Pedipalp, lateral view. c. Chelicera, lateral view. d. Leg I, lateral view.

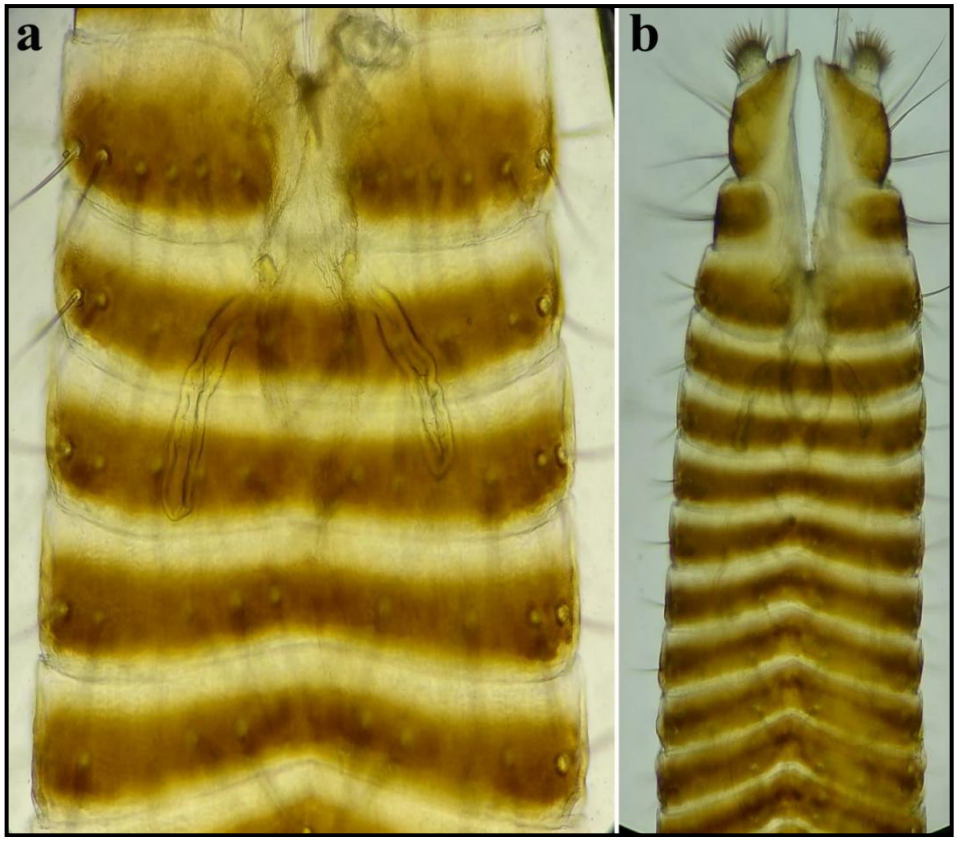


Fig. 2. *Egaenus turcicus*, female, Türkiye. a. Seminal receptacles. b. Distal part of the ovipositor.

Description: Male: For a detailed description, see Snegovaya & Marusik (2012).

Female: Body (Fig. 1a): Body length 11.6, width 5.50; The body with dark brown and covered with patches of light brown and black micro granules. The dorsal side of the body is marked by a light brown line that runs along its entire length. Eye mound low, covered with 2-3 black micro denticles in two rows.

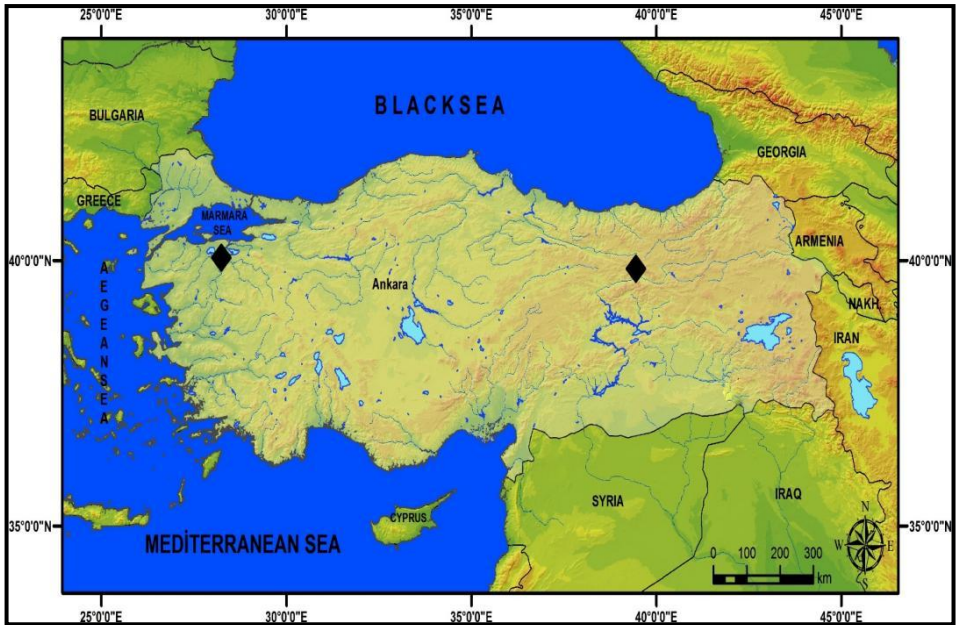
Chelicerae (Fig. 1c): not enlarged, normally structures. Basal segment without ventral spur, dorsally with setae and several denticles. Distal segment with only setae. Basal segment length:1.5; distal segment: 2.5.

Pedipalp (Fig. 1b): femur ventrally with black-tipped denticles and setae, dorsally with setae. Patella dorsally and ventrally with setae, ventro-distally with a black denticles. Tibia dorsally and ventrally with setae; ventro-distally with 2-3 black micodenticles. Metatarsus with setae and hairs.

Legs (Fig. 1d): The first pair of legs is slightly thickened. All legs covered with setae. I: 14,8 (3.1); II: 22 (4.5); III: 15.0 (3.2); IV: 22.4 (4.8) (The numbers within parentheses indicate the length of the femur).

Seminal receptacles (Fig. 2): A pair of long, thin tubes located on each of the 4th-5th segments.

Distribution (Map. 1): This species is only known from Türkiye (Snegovaya & Marusik, 2012).



Map.1. Distribution of *Egaenus turcicus* (♦) in Türkiye.

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Reproductive biology and hatching dynamics of *Paragaleodes occidentalis* (Simon, 1885) (Solifugae: Galeodidae) in Algeria

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Abstract

This study presents the first comprehensive observations on the reproductive biology of *Paragaleodes occidentalis* in Algeria. Captive monitoring revealed a pattern of strictly synchronized parturition, producing a homogeneous cohort of juveniles, alongside the expulsion of a substantial number of unfertilised or non-viable eggs. Overall, the calculated hatching rate was approximately 33.3%, consistent with values reported for other ovoviviparous *Galeodidae*. The findings indicate that embryonic mortality is likely influenced by maternal physiological condition and microclimatic factors, reflecting adaptive reproductive strategies in arid environments. These results provide new insights into the reproductive ecology of *P. occidentalis* and establish a baseline foundation for future studies on gestational physiology, embryonic viability, and population dynamics in desert and steppe habitats of North Africa.

Keywords: *Paragaleodes occidentalis*, Solifugae, reproductive biology, ovoviviparity, Algeria.

Introduction

The family Galeodidae represents one of the most diverse groups of Solifugae in Algeria, comprising the genera *Galeodes*, *Paragaleodes*, and *Othoes*, all of which exhibit strong adaptations to arid and semi-arid environments (Simon, 1879; Roewer, 1932). Their widespread occurrence across a broad range of xeric habitats reflects a high degree of ecological plasticity, which is a key factor contributing to their evolutionary success in harsh desert regions (Harvey, 2003). Despite this diversity, the Solifugae remain poorly studied in North Africa, particularly regarding their reproductive biology and behavioural ecology.

The limited available studies indicate a pattern of seasonal reproduction, synchronous hatching, and a high proportion of non-viable eggs, patterns previously documented in several species, including *Eremobates* spp. (Muma, 1966; Punzo, 1997, 1998a; Cloudsley-Thompson, 1975). These traits are essential for understanding reproductive strategies within the order, especially under the extreme environmental pressures characteristic of arid ecosystems.

Paragaleodes occidentalis (Simon, 1885) whose presence in Algeria was confirmed only recently (Sadine & El Bouhissi, 2019), had not previously been the focus of a dedicated reproductive study prior to this work. The observations carried out in captivity during the present study provide new and valuable insight, including accurate counts of juveniles at parturition and the number of unfertilised eggs within a single brood. This information is of particular relevance, as the simultaneous emergence of juvenile cohorts in strictly solitary arachnids such as Solifugae represents a key indicator for elucidating reproductive dynamics, hatching timing, and survival strategies in extreme environments.

Material and Methods

Most species of the order Solifugae exhibit strictly nocturnal activity (Cloudsley-Thompson, 1961). However, some species are partly or fully diurnal, reaching peak activity during the hottest periods of the day, which makes their observation and collection particularly difficult (Punzo, 1998a). Depending on the species, these arachnids occupy a wide range of microhabitats, including temporary shelters beneath stones and rocks, crevices within rocky substrates, and protected sites under decaying vegetation or livestock dung (Lawrence, 1963; Brookhart, 1972; Gore & Cushing, 1980).

In the present study, specimens were located and hand-collected during the summer season, mainly from beneath stones (Fig. 1B, 1C) and among grass tussocks (Fig. 1B), indicating a preference for open habitats with sparse herbaceous cover. Taxonomic identification of the collected specimens was performed using he key of Roewer (1934).

An adult female of *P. occidentalis* was kept in captivity in a terrarium containing a slightly moistened sandy-loam substrate (10-15% humidity) under controlled temperatures ranging between 28 and 32°C. The female was daily monitored to follow the progression of gestation. At parturition, all juveniles were immediately counted. Unfertilised eggs, expelled as yellowish masses, were also collected and counted separately.

The hatching rate was calculated as follows

$$Hatchig\ rare\ (\%) = \frac{Number\ of\ juveniles}{\text{Number of juveniles } + \text{Number of unfertilised eggs}} X100$$

Taxonomic situation of the studied species

Family ***Galeodidae*** Sundevall, 1833
Genus ***Paragaleodes*** Kraepelin, 1899
Paragaleodes occidentalis (Simon, 1885) (Fig. 1)

Synonyms (Harvey, 2003; World Solifugae Catalog, 2025):
Galeodes barbarus Lucas: Simon, 1879: 102-103, (misidentification).
Galeodes occidentalis Simon, 1885c: 44; Roewer, 1934: 534; Zilch, 1946: 146.
Paragaleodes occidentalis (Simon): Kraepelin, 1899b: 204; Kraepelin, 1899c: 376; Kraepelin, 1901a: 25-26; Kraepelin, 1908c: 214, fig. 40; Simon, 1909a: 41; Berland, 1932: fig. 39; Harvey, 2003c: 275.
Type locality: Morocco.
Distribution: Algeria, Mauritania, Morocco.

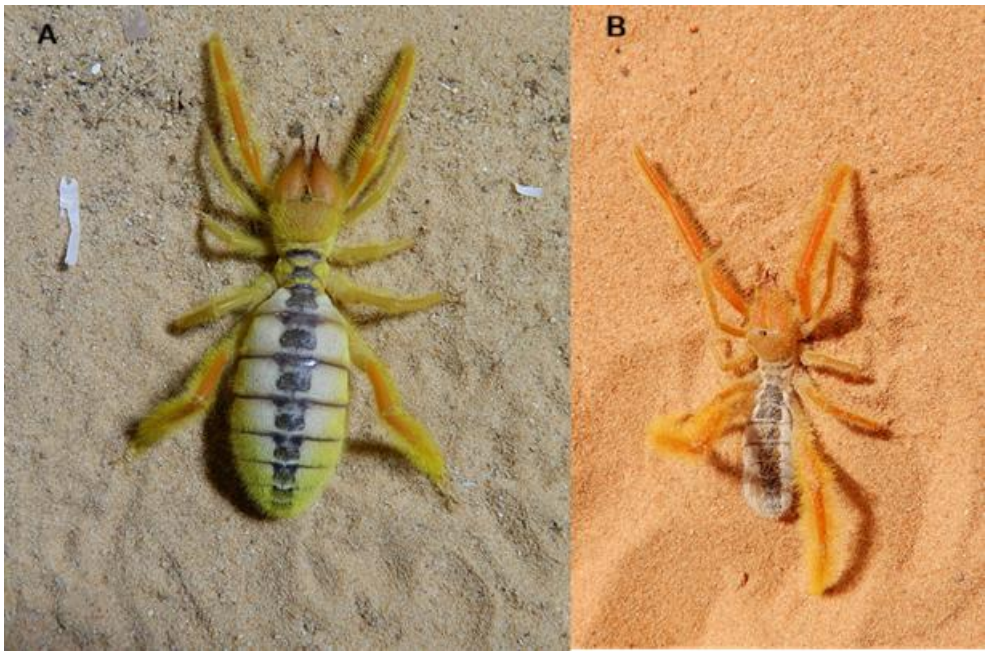

Fig. 1. *Paragaleodes occidentalis* in natural habitat, both male and female observed in a steppe formation of the Tiaret region. A. Female. B. Male.

Results and Discussion

For the examined female, parturition produced 25 juveniles, their emergence was strictly synchronised, a characteristic frequently reported in ovoviviparous Solifugae. The neonates exhibited relatively uniform size, indicative of consistent internal embryonic development.

Following parturition, the female also expelled approximately 50 unfertilised or non-viable eggs. The elimination of such residual structures is well documented in ovoviviparous taxa, in which unfertilised eggs may remain within the oviduct during gestation and are expelled during or immediately after the birth of the young.

Considering all reproductive products expelled (juveniles plus non-viable eggs), the calculated hatching rate was 33.3%. This value falls within the ranges reported for other ovoviviparous Galeodidae and represents the first reliable estimate for *P. occidentalis* under controlled conditions.

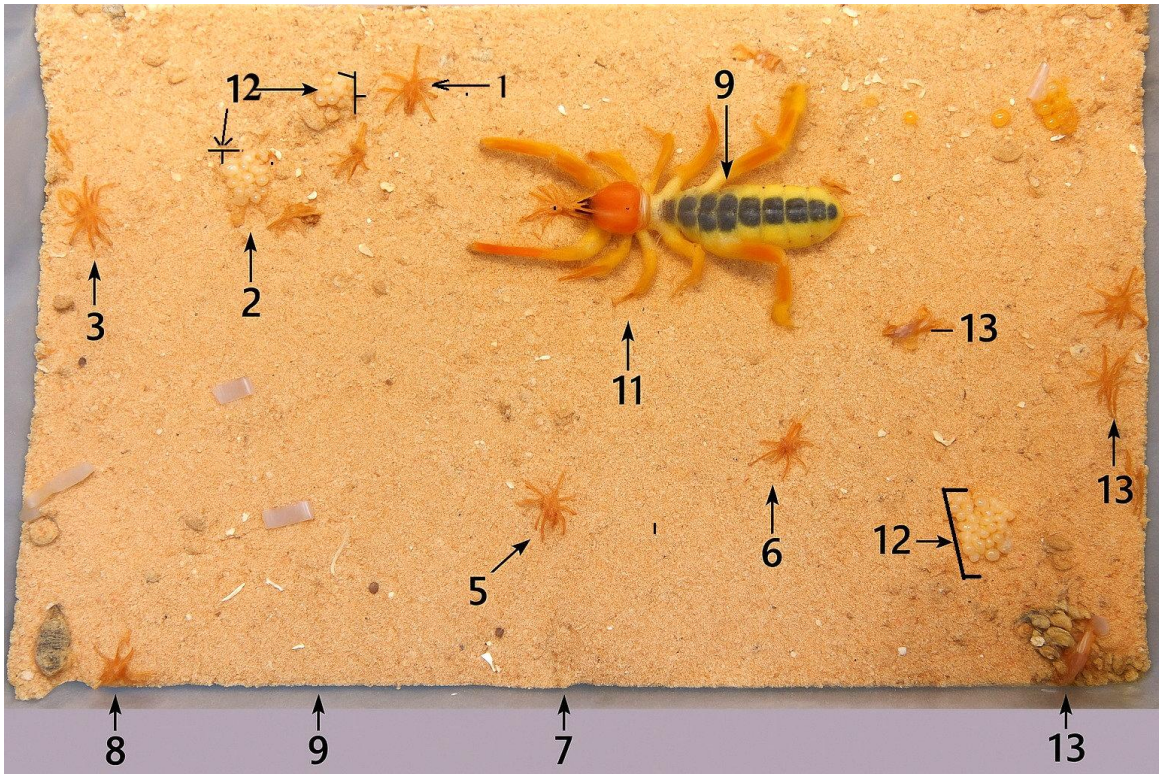

Fig. 2. Hatching *Paragaleodes occidentalis* in captivity showing the female surrounded by newly emerged juveniles (1-25) and 12 clusters of unfertilised egg masses (≈ 37-40 united).

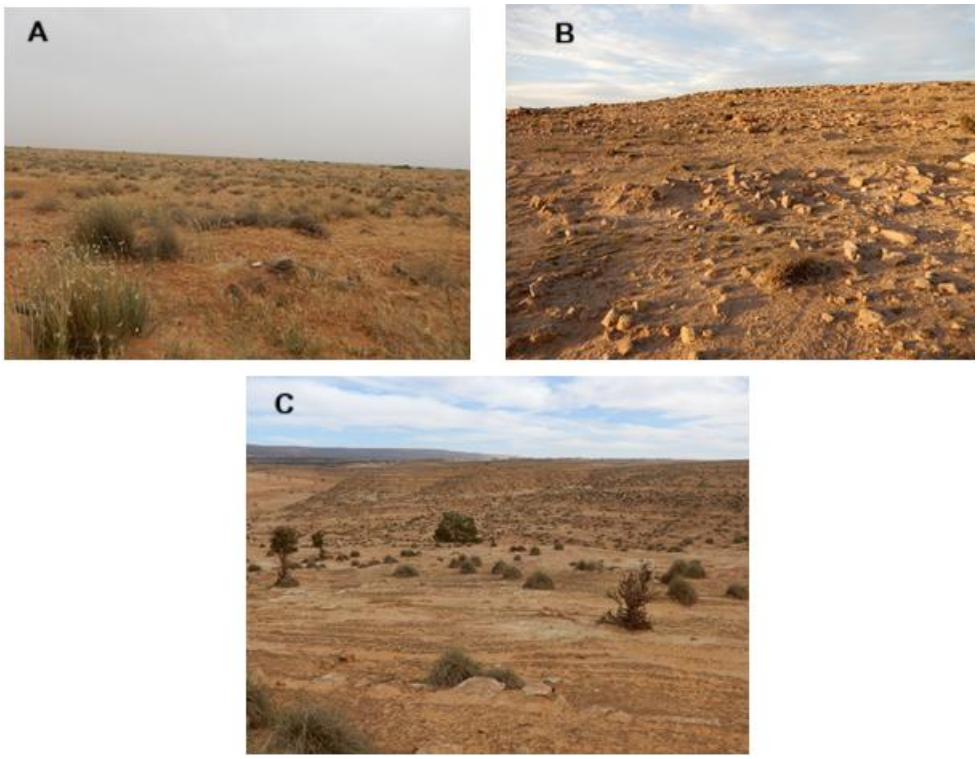

Fig. 3. Natural habitat of *P. occidentalis.* A-B. Ain Dheb locality, Tiaret, showing typical steppe formations. C. Rosfa, Tiaret locality, stony plain.

The results obtained correspond closely with the classical observations reported for Solifugae. Several foundational studies including those of Punzo (1998a, 1998b), Muma (1963, 1966), and Cloudsley-Thompson (1961, 1975) indicate that reproduction in many species is characterised by synchronised hatching followed by varying levels of embryonic mortality, depending on species-specific traits and environmental factors.

The 33% hatching rate recorded in this study aligns with the values generally documented for Galeodidae, where simultaneous emergence of the young is frequently accompanied by a considerable number of non-viable embryos. The presence of approximately 50 unfertilised eggs is also a well-known phenomenon in Solifugae and may be attributed to various factors, including the physiological condition of the female, spermatophore quality, and microclimatic parameters, particularly sensitivity to temperature and humidity, as highlighted by Cloudsley-Thompson (1975).

Comparable patterns have been reported in other Solifugae, especially in *Eremobates* spp., where Muma (1966) and Punzo (1997, 1998a) also described synchronised emergence and high rates of embryonic mortality. Collectively, these observations indicated that the reproductive patterns recorded for *P. occidentalis* are consistent with the general reproductive strategy of Solifugae inhabiting arid environments.

This study thus constitutes the first detailed and reliable description of the reproductive cycle of *P. occidentalis* in Algeria, providing new insights into the reproductive biology of the group. Furthermore, the findings highlight promising ways for future research on reproductive ecology, embryonic physiology, and the influence of climatic constraints on reproductive success.

Conclusion

The observations conducted in captivity on *P. occidentalis* provide the first reliable reproductive data for the species in Algeria. The results demonstrate a synchronised parturition, producing a homogeneous cohort of juveniles, consist with the reproductive patterns described for ovoviviparous *Galeodidae*. The simultaneous expulsion of a large number of unfertilised or non-viable eggs—representing roughly two-thirds of all reproductive structures—corroborates earlier reports of high embryonic mortality in Solifugae, which is strongly influenced by maternal physiological condition and microclimatic factors.

The 33.3% hatching rate, although apparently low, falls within the ranges documented for related taxa and reflects the reproductive constraints typical of arachnids adapted to arid environments. These findings highlight a reproductive cycle marked by significant embryonic selection, likely linked to the ovoviviparous strategy of the species.

Overall, this study represents a significant advance in our understanding of *P. occidentalis* reproductive biology, a taxon that has remained largely unstudied until now. It opens new ways for investigating gestational physiology, ecological factors affecting embryonic viability, and the population dynamics of Solifugae in the steppe and desert environments of North Africa.

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An evaluation of external morphology of *Hottentotta saulcyi* (Simon, 1880) (Scorpiones: Buthidae)

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Abstract

The comparative external morphological structures were surveyed on male and female *Hottentotta saulcyi* (Simon, 1880) in detail with scanning electron microscope (SEM). The constellation arrays on chelae, peg sensilla on the pectinal organ, aculear peg sensilla on aculeus part of telson, femoral cluster setae and trichobothria on chelae, and the other sensillar structures (sensilla trichodea, sensilla chaetica, slit sensilla) and epicuticular patterns on chelicerae, legs, and their functional morphologies were assessed in light of habitat and climatic preferences of both sexes of the species. This study constitutes the first comprehensive investigation of the external morphology of *H. saulcyi.*

Keywords: *Hottentotta*, constellation arrays, pectinal organ, aculear peg sensilla, femoral cluster setae, slit sensilla.

Introduction

Scorpiones constitutes the fourth most speciose order of arachnids (excluding Acari) worldwide, following Araneae, Opiliones, and Pseudoscorpiones (Blick & Harvey, 2011). At present, this highly diverse order encompasses 22 families, 265 genera, and 2922 described species (Rein, 2026). The focal species of this study, *Hottentotta saulcyi* (Simon, 1880), belongs to the family Buthidae, which is represented by 94 genera comprising 1288 species. Members of this family occur worldwide (absent only from

Antarctica and New Zealand) and inhabit tropical, subtropical, and, to a lesser extent, temperate regions. Zoogeographically, *H. saulcyi* originates from the Irano-Turanian region and occurs in Iraq, Iran, Syria, and Türkiye (Demirsoy & Yağmur, 2024). In scorpions, the sensory system comprises a diverse array of specialized structures, including the constellation array, median and lateral eyes, femoral cluster setae on the chela, pectinal and aculear peg sensilla, slit sensilla, trichobothria, and setae of varying thickness and length. These components collectively function as mechanoreceptors, chemoreceptors (including hygro- and thermoreceptors), and proprioceptors, enabling the detection of environmental stimuli and spatial orientation. (Barth & Stagl, 1976; Foelix & Müller-Vorholt, 1983; Foelix & Schabronath, 1983; Messlinger, 1987; Polis, 1990; Gaffin & Brownell; 1997; Fet *et al*., 2006a, b; Stockmann & Ythier, 2010; Benli *et al*., 2013; Foelix *et al*., 2014; Hussen *et al*., 2023; Erdek & Yağmur, 2024; Lowe & Tang, 2024; Lowe & Fet, 2024; Lowe, 2024).

This study provides a detailed characterization of the sensillar and epicuticular structures in male and female *H. saulcyi*, with particular emphasis on their functional morphological implications.

Material and Methods

Adult specimens of *Hottentotta saulcyi* were actively collected at night using UV light and forceps from the city centre of Hakkari Province, Türkiye (37°34′15″N, 43°45′20″E, 1742 m; 37°34′18″N, 43°45′20″E, 1744 m) during July-August 2025. Specimens were photographed and documented using a Leica DFC295 digital camera. For scanning electron microscopy (SEM), selected morphological structures—including the chelicerae, pectinal organs, chelae, telsons, carapace, and legs I and IV of both sexes—were dissected and immersed overnight in absolute ethanol. Following dehydration, samples were gold-coated using a Quorum SC7620 sputter coater. SEM imaging was performed at an accelerating voltage of 10 kV using a ZEISS Sigma 300 microscope housed at the Science Application and Research Center of Van Yüzüncü Yıl University. All examined material are deposited in the Arachnida collection of the Zoology Museum, Hakkari University.

Results

The overall morphology of male and female *H. saulcyi* is illustrated in Fig. 1 (A-D).

The External Morphology of Chelae. (Figs. 4-5). There are constellation arrays at the tip of the chelal fixed fingers on retrolateral surfaces in both sexes (Figs. 2A-F). The clusters of sensillar structures in constellation arrays consist of 11 basiconic sensilla in males and 10 basiconic sensilla in females (Figs. 2E-F). Each basiconic sensillum is located in a large pit-shaped socket. The average length of these basiconic sensilla in the female is 2.97µm and the width of the concave socket to which it is attached is 4.45µm (Fig. 2E). The average length of these basiconic sensilla in the male is 3.47µm and the width of the concave socket to which it is attached is 5.04µm (Fig. 2F). A few wax openings and cuticular pits were observed on the chela surface (Figs. 2D, 3E-F). Only a few trichobothria are present, occurring at irregular intervals—particularly along the fixed fingers of the chela (Figs. 2A-B; 3A-B). There are short and spindly falciform setae with wedge-shaped tips located near the tip of the chela (Figs. 2C-D, 9E). A honeycomb-like cuticular pattern is present in both sexes chelal surface, particularly prominent on prolateral surface (Figs. 2C-D; 3C-F). In both sexes, the chela surface is covered with numerous short, medium-hard setae in the form of sensilla trichodea (Figs. 2A-D, 3A-B).

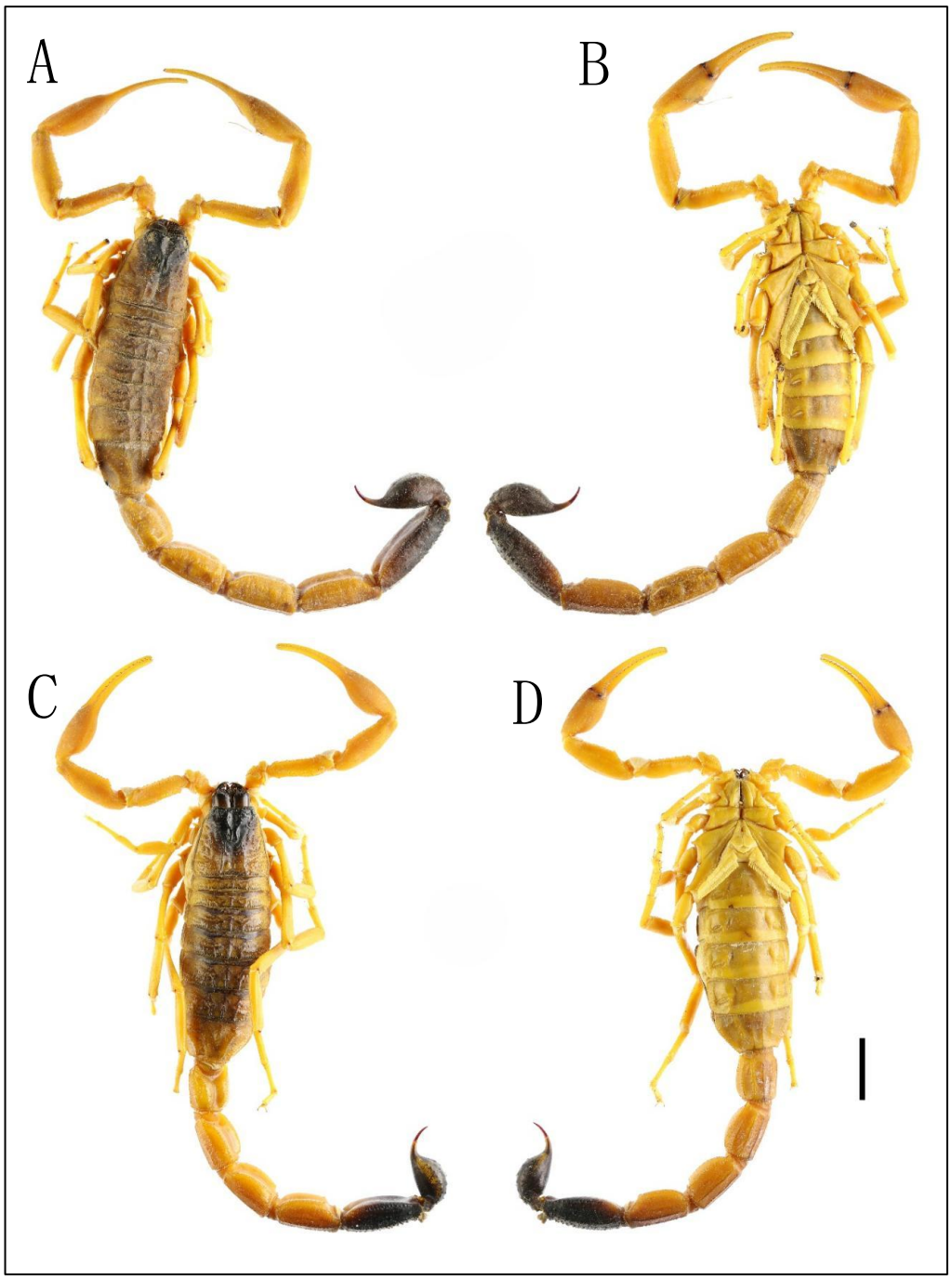

Fig. 1. *Hottentotta saulcyi* (Simon, 1880). A, B. male. C, D. female. A, C. dorsal view. B, D. ventral view. (Scale bar: 1 cm).

The prolateral region of the chela's fixed finger bears single slit sensillum, occurring sporadically near the dental margin. In the female, this number is higher and arranged more regularly (Figs. 3A-D). The retrolateral surface of the femur of chela is subdivided into upper and lower regions by a prominent median carina, which is externally visible and characterized by granular ornamentation (Figs. 4A-D). The macrosetae are more prominent in females than in males. In males, the macrosetae are comparatively thinner, more irregular in distribution, and more widely spaced than in females.

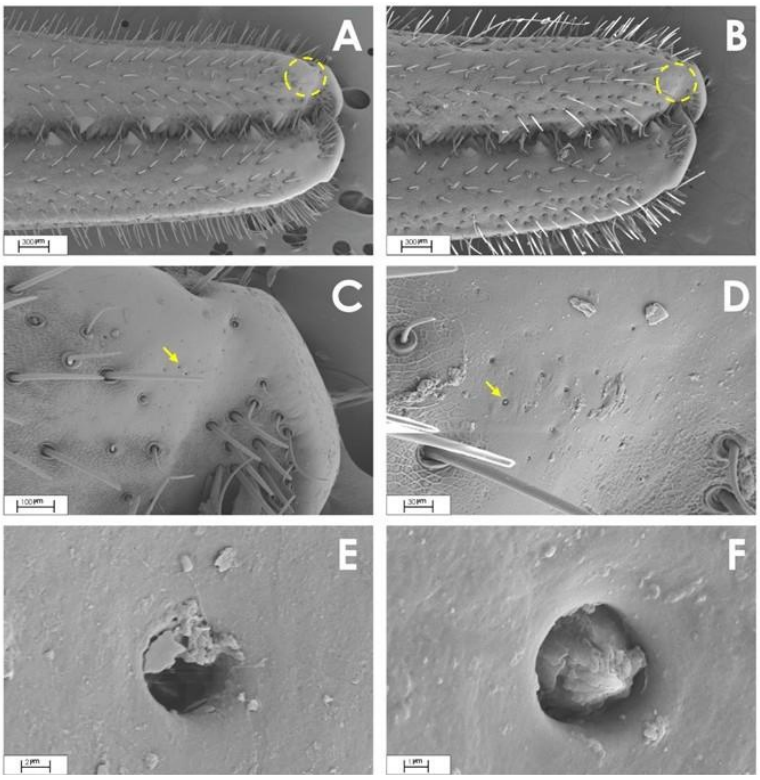

Fig. 2. *Hottentotta saulcyi* (Simon, 1880). A, C, E. female. B, D, F. male. A-B. the chela of pedipalp in retrolateral view (The areas of constellation array indicated by circles). C-D. the constellation array. E-F. the single basiconic sensillum with wax openings.

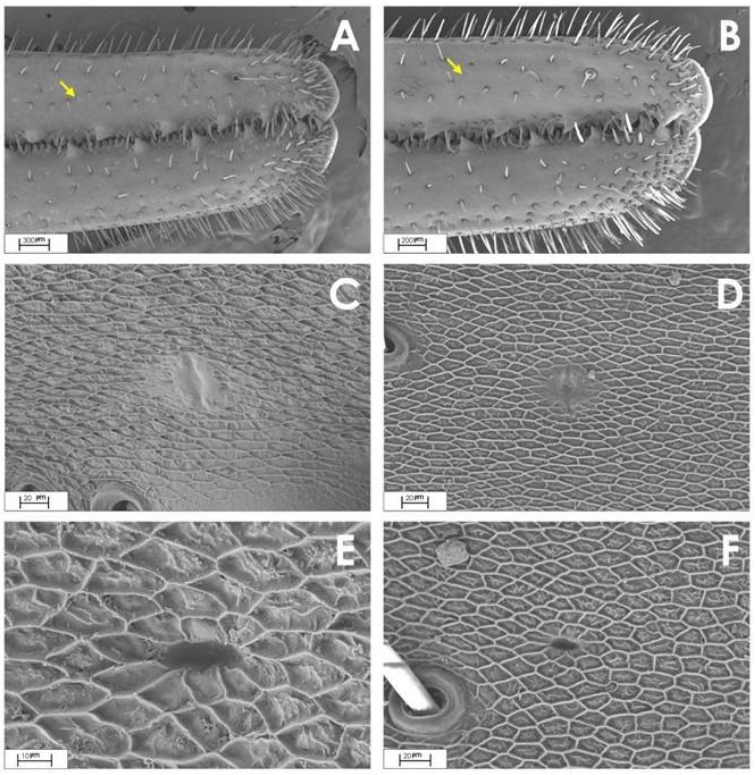

Fig. 3. *Hottentotta saulcyi* (Simon, 1880). A, C, E. female. B, D, F. male. A-B. the chela of pedipalps in prolateral view. C-D. the single slit sensillum on chelar surface. E-F. epicuticular pits and honeycomb-like pattern.

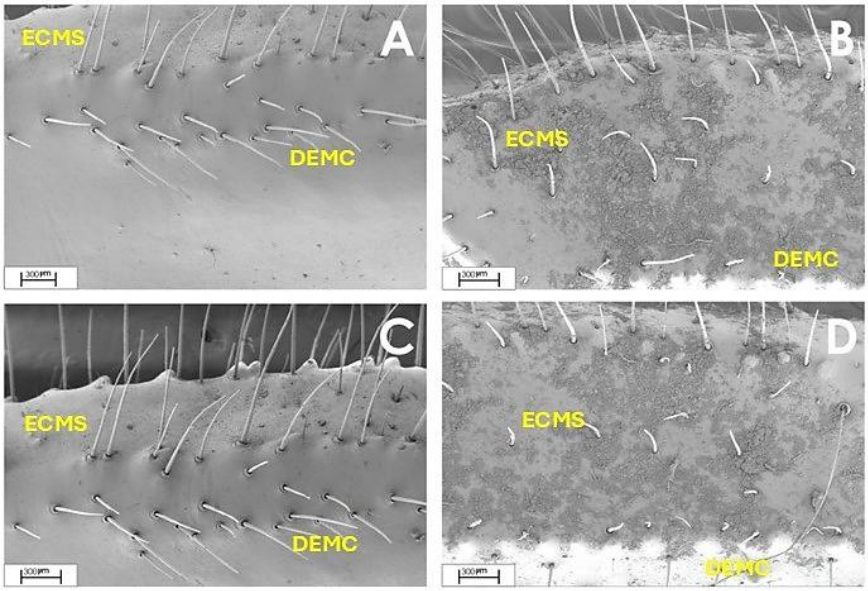

Fig. 4. *Hottentotta saulcyi* (Simon, 1880). A, C. female. B, D. male. A-B. the surface of pedipalp femur, external aspect. C-D. clustered macrosetae on the external aspect of the pedipalp femur. (DEMC: distal external macrosetal cluster, ECMS: external carinal macrosetal series).

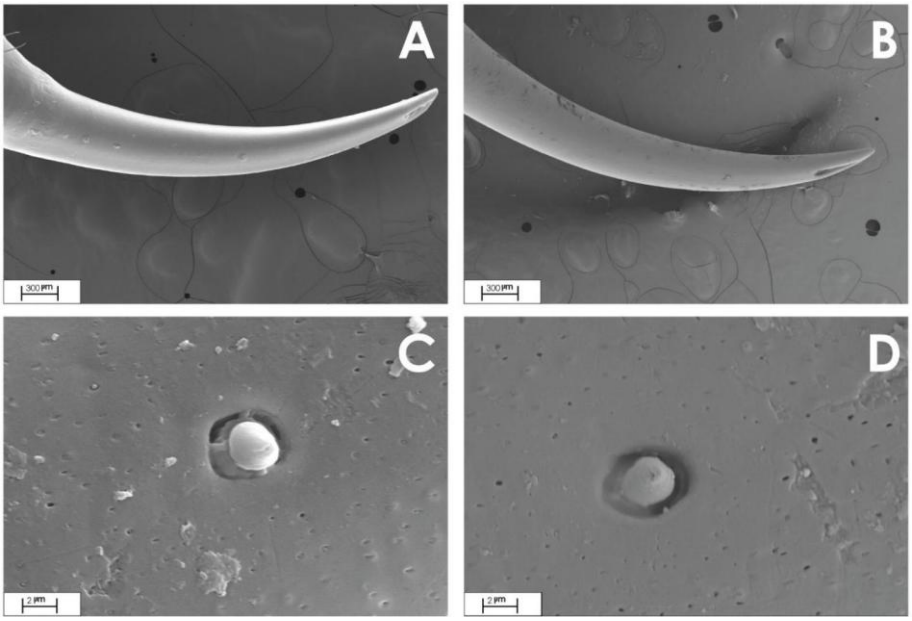

Fig. 5. *Hottentotta saulcyi* (Simon, 1880). A, C. female. B, D. male. A, B. the aculeus part of telson and venom pore in lateral view. C, D. aculear peg sensillum in detail and pore holes on the cuticular surface of aculeus.

The External Morphology of Telson. (Fig. 5). The telson typically consists of two parts: the bulb and the aculeus. The subapical region of each aculeus (stinger) is characterized by the presence of two venom pores (Figs. 5A-B). The distal end of each venom pores is acuminative, tapering progressively to a narrow point (Figs. 5B, 6A). Each aculear peg sensillum on the aculeus is anchored within a broad, oval socket. Morphologically, it exhibits a cylindrical base that tapers near the cuticular surface of the aculeus and

transitions into an oval-conical form towards the distal apex (Figs. 5C-D). The surface of the aculeus is uniformly perforated with pore openings in both male and female specimens across all examined species. The folded, wrinkled structure seen at the top of Fig. (6B) represents the surface of the venom gland. The surface features clusters of tubercle-like protrusions at regular intervals (Fig. 6B). Fig. (6C) shows the longitudinal view of the muscle fibers surrounding the gland and their folded, layered structure. On the inner surfaces of stinger walls, there are many cuticle pore holes as shown in Figs. (6E-F). There are pores of various sizes, and around these are numerous smaller pore structures, referred to as hierarchical pore structures (Fig. 6F).

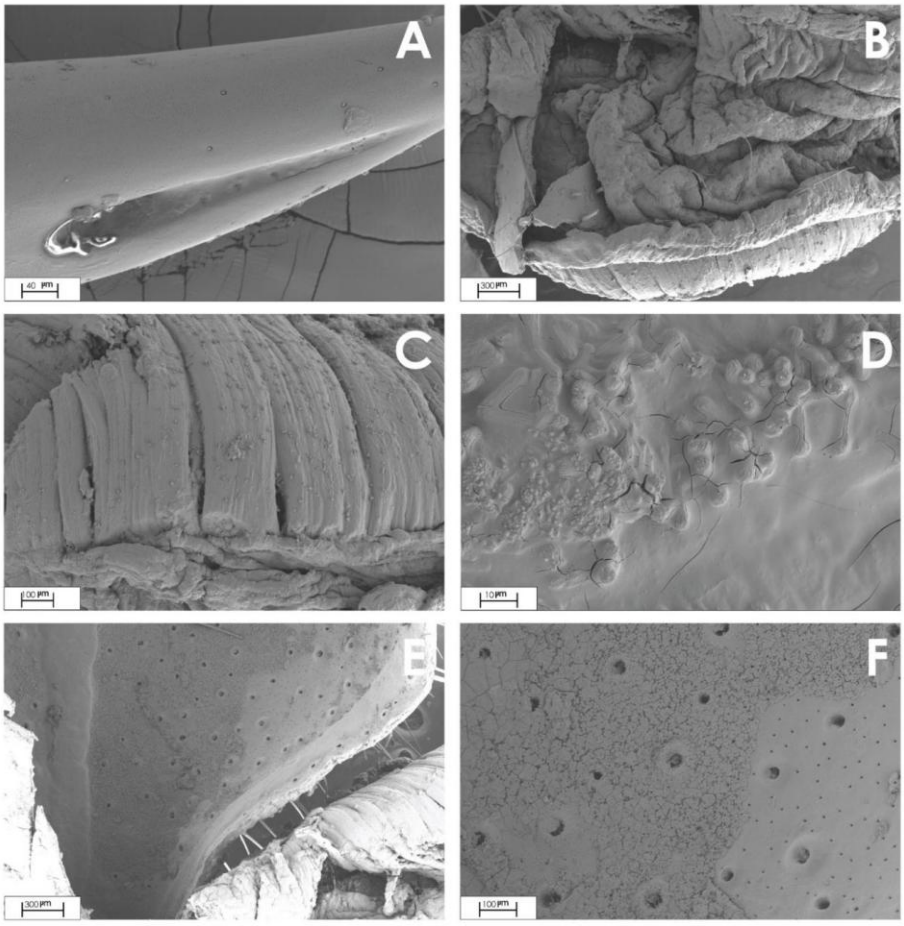

Fig. 6. *Hottentotta saulcyi* (Simon, 1880). A-F. female: A. venom exit opening. B. venom gland. C. longitudinally striated muscle structures around the venom gland. D. swollen structures on the inner surface of the cuticle near the aculeus. E. cuticular pore holes on inner side of bulb walls. F. close-up of the pore holes.

The External Morphology of Pectinal Organ (Fig. 7). Pectines are bilateral, comb-like appendages located adjacent to the coxae of the fourth pair of legs on the ventral surface in both male and female specimens. The numbers of pectinal teeth are 30 in males and 24 in females (Figs. 1B, 1D, 7A-B). The quantity of peg sensilla distributed along individual pectinal teeth is markedly elevated in males relative to females (Figs. 7A-B). The average length of peg sensilla in males is 3.35 µm and in females is 4.06 µm. The apex of each peg sensilla is elliptical and has a sensory groove-like structure in the middle.

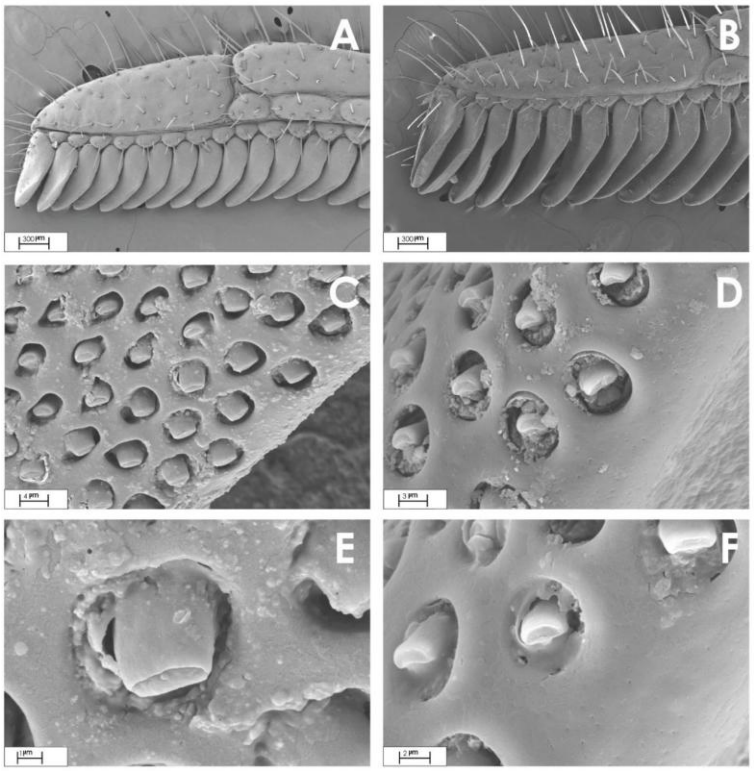

Fig. 7. *Hottentotta saulcyi* (Simon, 1880). A, C, E. female. B, D, F. male. A-B. pectinal organ. C-D. peg sensilla. E-F. peg sensilla in detail.

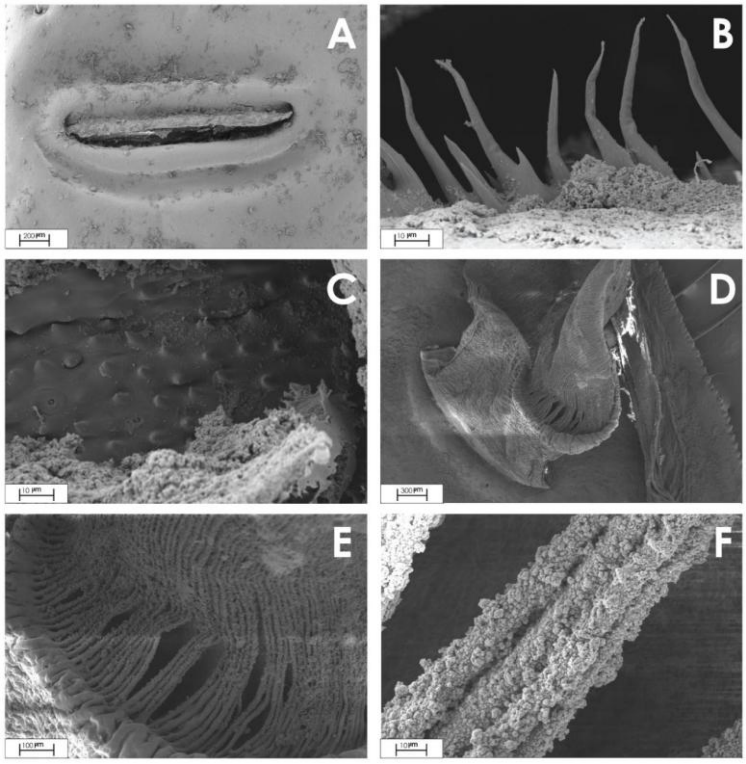

Fig. 8. *Hottentotta saulcyi* (Simon, 1880). A-C. female. D-F. male. A. spiracle. B. sub-tree like processes on spiracle edge. C. tubercular structures located near the inner surface of posterior spiraculum edge. D. book lung. E. book lung lamellae, distal lamellar edge. F. creased to wrinkled distal edges of book lung lamella.

The External Morphology of Spiracle and Book Lungs (Fig.8). In scorpions, the respiratory structures are located on the internal surface of the ventral exoskeleton within the mesosomal region. Each spiracle is oblong and slit-like in shape (Fig. 8A). The inner surface of the lip-like cuticular process bears branched, smooth-surfaced epicuticular projections (Fig. 8B). The posterior edge of spiraculum is with hillock-like structures (Fig. 8C). A pair of book lungs is positioned laterally on the sternites of the third through sixth visible mesosomal segments, posterior to the pectinal segment. Each book lung is composed of a series of leaf-like lamellae arranged in stacked layers above the ventral sternite (Figs. 8D-E). The distal edges of book lamellae have wrinkled surface (Figs. 8E-F).

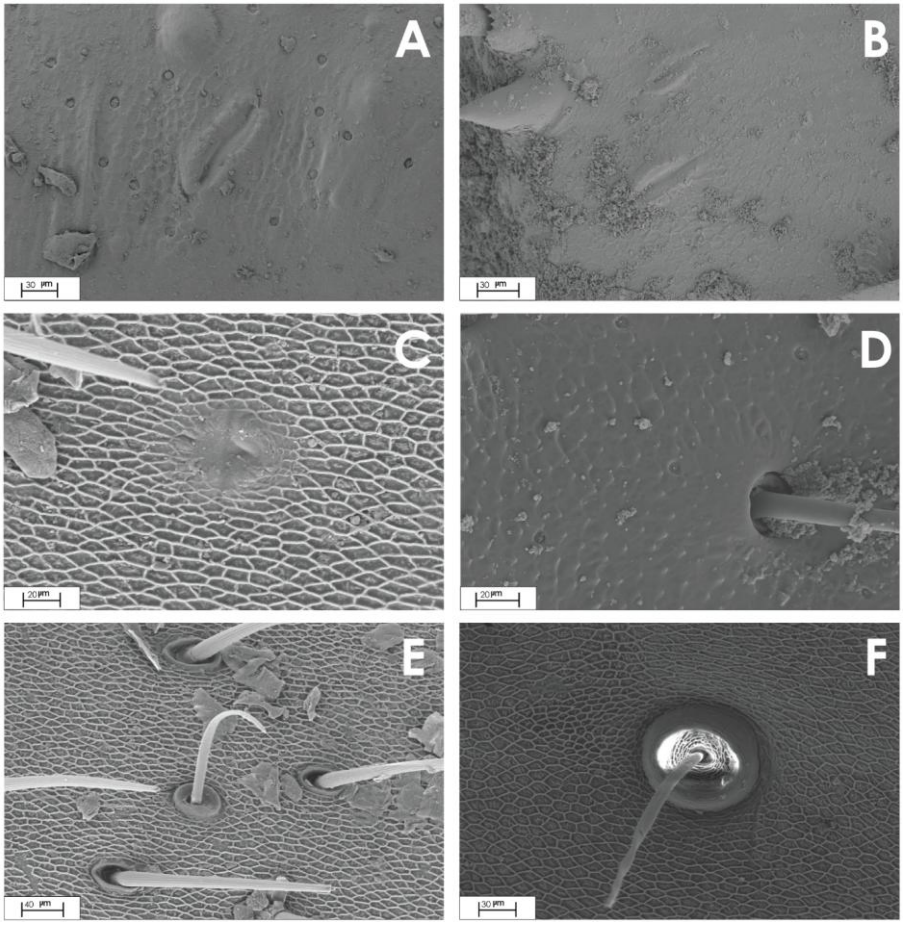

Fig. 9. *Hottentotta saulcyi* (Simon, 1880). A. single slit sensillum and surrounding wax openings on female carapace. B. grouped single slit sensilla on the 3rd leg tibia of male. C. single slit sensillum and cuticular pattern of the retrolateral surface of male chela. D. wax openings on the prolateral surface of female chelicera. E. falciform hairs and sensilla trichodea on the retrolateral surface of male chelicera. F. trichobothria on the prolateral surface of male chela.

There are numerous wax openings on the carapace in both sexes. The female also has occasional single slit sensilla (Fig. 9A). Single-, double-, and triple-slit sensilla were observed on the distal portions of the walking leg segments, with a higher frequency in females (Fig. 9B). In both sexes, irregularly spaced single-slit sensilla occur on the prolateral and retrolateral surfaces of the chela (Fig. 9C). Wax openings were observed on

the carapace surface, although they were more numerous than on the chela, chelicerae, and bulb part of the telson surfaces in both sexes (Fig. 9D). Falciform setae have been observed at the apex of the chelae, on the retrolateral surface of the movable fingers of the chelicerae, and in the anterior part of the carapace, around the lateral eyes (Fig. 9E). A few trichobothria are present at irregular intervals, particularly on the fixed fingers of the chela. Each trichobothrium is filiform, and its socket consists of intertwined circular structures (Fig. 9F).

Discussion

Hottentotta saulcyi (Simon, 1880) is distributed in the southeastern border region of Türkiye, in the provinces of Şanlıurfa, Mardin, Batman, Şırnak, and Hakkari. They are generally found in areas with an average altitude of 500-1100 m (Demirsoy & Yağmur, 2024). In this study, however, the altitude was measured as 1742-1744 m. The species is associated with basaltic or limestone rocky environments, where it is commonly found under large stones, inside stone walls, and in dry, rocky habitats. It has been reported that this species, similar to *Androctonus turkiyensis* Yağmur, 2021, exhibits anthropotolerant behaviour (Demirsoy & Yağmur, 2024). These species reproduce in spring and exhibit sustained activity during both the spring and summer periods. The area in this study from which the samples were collected lies within human-inhabited spaces, and it has been reported that scorpions occasionally enter houses during the summer months, although stinging incidents are rare. Considering the climate and habitat conditions, the species has developed some specialized sensory structures, such as sensilla and epicuticular structures, to adapt to extreme condition.

In both sexes, three distinct types of aporous sensilla are generally present on different body surfaces; *Sensilla basiconica* (SB), *Sensilla chaetica* (SC), *Sensilla trichodea* (ST). Each peg within the constellation array corresponds to SB. Positioned on the external aspect of the distal region of the chelal fixed finger, the constellation array is interpreted as a chemosensory sensillum/organ in scorpions (Fet *et al.*, 2006a). According to Fet *et al.* (2006b), analyses of constellation arrays in species from four genera of the Vaejovidae revealed that sensillum counts are variable across taxonomic groups at several hierarchical levels. Hussen *et al.* (2023) proposed that the constellation array, present in both sexes, may function as a chemoreceptor—potentially involved in hygro- or thermo-reception—based on its position on the pedipalp within the habitat. The rigid and immobile setae located in the tarsus and metatarsus segments of the legs, and the setae located on the inner surface of the chelicerae, are of the SC type and function as mechanoreceptors. The ST located on the chelicerae, characterized by its thin and flexible structure, is presumed to act as a contact chemoreceptor associated with gustatory sensing (Hussen *et al.*, 2023). The trichobothria on the surface of the chela and the short/weak ST detect changes in airflow, the movements of approaching predators or prey, and even vibrations. Trichobothria function as highly sensitive mechanoreceptors (Messlinger, 1987; Root, 1990; Hussen *et al.*, 2023).

In scorpions, slit sensilla serve as cuticular mechanoreceptors functioning as proprioceptors, enabling the detection of strain and substrate-borne vibrations during movement. Three types of slit sensilla are recognized: isolated slit sense organs, groups of single slits, and lyriform (compound) slit sense organs. It is thought that it may detect vibrations from prey to locate food (Barth & Stagl, 1976; Hussen *et al.*, 2023). In *Hottentotta saulcyi*, a single slit sensillum and groups of single-slit sensilla are present on the legs, chelae, and carapace. According to Lowe (2024), the aculeus itself does not fluoresce; however, the aculear peg sensilla, aculear sensilla coeloconica, on the cuticle

surface exhibit fluorescence that penetrates into the inner cuticular layers. Lowe (2024) stated that also aculear sensilla coeloconica are likely ubiquitous across the scorpions and play an essential role in the sensory coordination of telson function during prey envenomation. Erdek & Yağmur (2024) claimed that during the stinging action, the entire aculeus is inserted into the victim's tissue. The aculeus is also thought to function as a contact chemoreceptor, detecting changes in tissue temperature, depth, and tightness either before or during venom release. Our observations support this interpretation. The lamellar surface of the book lung in *Hottentotta saulcyi* shows no resemblance to that of any *Hottentotta* species examined by Kamenz *et al.* (2008). This situation may be due to differences in the habitats and climatic conditions preferred by the species.

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Comparative dynamics of offspring growth in *Mesobuthus eupeus* (C.L. Koch, 1839) and *Olivierus caucasicus* (Nordmann, 1840) (Scorpiones: Buthidae)

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Abstract

The main aspects of offspring growth in two scorpion species – *Mesobuthus eupeus* and *Olivierus caucasicus* were studied. The entire reproductive cycle – mating, pregnancy of females, birth of the offspring and their growth until adulthood – took place in laboratory conditions. The duration, rate, and intensity of growth, as well as the dynamics of body weight changes and some metric traits during post-embryonic ontogenesis were studied. The growth of young scorpions was uneven, with growth periods of varying lengths: from larva to third molt – an average of 6.2 months, from the fourth molt to the sixth (imago) – an average of 12.6 months (*M. eupeus*); and an average of 7.7 and 14.1 months (*O. caucasicus*). By duration of development, *M. eupeus* nymphs were ahead of *O. caucasicus* nymphs: on average by 9.2±2.8 days in early post-larval ontogenesis and by 15.0±3.5 days in late post-larval ontogenesis. Of the entire growth cycle, 4/5 occurred during molting, the remaining 1/5 occurred in the periods between molting. Species-specific and sex-specific differences in the dynamics of changes in linear characters and body weight were identified. Sexual dimorphism was also evident in faster development, a greater number of molts, and a longer lifespan in females compared to males. Changes in growth rate and intensity tended to increase at the beginning of development and decrease at the end. Nymphs of both species also showed some decrease in growth rate and weight gain during periods of no feeding activity before molting and during periods chronologically corresponding to their natural diapause in the wild.

Keywords: Scorpions, offspring, juveniles, growth, post-embryogenesis, weight, length.

Introduction

The dynamics of growth in post-embryonic ontogenesis of scorpions varies significantly depending on the species, characters of individual development, metabolic rate, temperature balance of the habitat and feeding ecology. The data available in the literature on the growth and metabolism of scorpions at the stage of postembryonic ontogenesis are devoted to a relatively small number of species (Auber, 1963; Dresco-Derouet, 1964, 1967; Hodley & Hill, 1969; Lourenço, 1979; Polis & Sissom, 1990; Brown, 1997; Zotin *et al.*, 1998). In recent decades, breeding of scorpions in scorpion farms and in specialized laboratories has become a particularly priority area for the use of zootoxins in medicine and agrobiotechnology. Data on the growth dynamics of many scorpion species promising for venom extraction are very limited, although their importance for successful scorpion breeding is significant. Therefore, assessing the reproductive potential of scorpions remains extremely important from a scientific and practical point of view. One approach to such assessment could be to obtain additional information on the growth dynamics at different stages of development of scorpion species promising for venom extraction, with the aim of successfully breeding them and creating viable artificial populations.

According to modern data, three species of scorpions belonging to three genera within the family Buthidae C.L. Koch, 1837 inhabit the Lesser Caucasus (within Azerbaijan): the genus *Mesobuthus* Vachon, 1950 – *Mesobuthus eupeus* (C.L. Koch, 1839); genus *Olivierus* Farzanpay, 1987 – *Olivierus caucasicus* (Nordmann, 1840), and genus *Androctonus* Ehrenberg, 1828 – *Androctonus crassicauda* (Olivier, 1807). The last species is difficult to keep and, moreover, in recent years its numbers have been greatly declining and therefore it is protected by law. The first two species are dominant and relatively unpretentious when kept in the laboratory. Information on the reproductive potential, the dynamics of growth and individual development of the offspring of *Mesobuthus eupeus* and *Olivierus caucasicus* at the post-embryonic ontogenesis is scarce, fragmentary and contradictory (Kobakhidze, 1950; Malinina, 1981; Yusubov, 1984).

The aim of this study is to conduct a more detailed examination and comparative analysis of the main aspects of linear growth and dynamics of body weight changes in the offspring of the above-mentioned dominant scorpion species of the Lesser Caucasus.

Material and Methods

The material for the study was the offspring of two species of scorpions of family Buthidae: *Mesobuthus eupeus* (C.L. Koch, 1839) and *Olivierus caucasicus* (Nordmann, 1840), formerly known as *Mesobuthus caucasicus* (Kovařík, 2019). The offspring were obtained by breeding adults in laboratory conditions. Adult scorpions were delivered from the Lesser Caucasus (Julfa District, Nakhchivan Autonomous Republic, Azerbaijan) (Table 1).

At the beginning of the study, we had four litters (n = 134 juveniles) of *M. eupeus* and three litters (n = 69 juveniles) of *O. caucasicus*. The juveniles were kept severally in plastic containers placed in a separate room with access to natural diffused light on a day/night cycle (9-14 Light: 10-15 Dark). Temperatures were maintained at 22-24°C at night and 26-30°C during the day (depending on the season), with humidity at 40-60%. The soil in containers with juvenile scorpions was not used for hygienic reasons. Each nymph was offered comparable-sized larvae of laboratory-reared insects twice a week. Uneaten prey or its remains were removed the next day. Cotton pads moistened with water were placed in the containers containing the scorpions as a source of moisture.

When keeping adult and young scorpions in laboratory conditions, artificial diapause was not provided to them, as this contradicted the objectives of the experiment. Over a four-year laboratory study period, the entire reproductive cycle of scorpions was observed, from mating of adults to the completion of offspring growth. Mortality among juveniles was observed at the larval stage (infanticide of females) and in the first half of post-larval ontogenesis and was caused by refusal of food during the first three months after birth, disruption of the second and third moults, and cannibalism. The surviving juveniles (53%), having completed all developmental stages (larval and six nymphal), reached adulthood.

Table 1. Size-weight parameters of adult male and female *Mesobuthus eupeus* and *Olivierus caucasicus* used to produce offspring in the laboratory.

Species	n (♂/♀)	Weight, g (♂/♀)	Character, mm					
			Tot.L		Met.L		Car.L	
			♂	♀	♂	♀	♂	♀
M. eupeus	6/11	0.89/1.2	40.3-45.1 41.28±0.35	40.6-50.2 42.81±0.26	24.1-26.3 25.40±0.22	23.6-26.6 24.80±0.22	4.9-5.7 5.35±0.03	4.8-6.1 5.52±0.05
O. caucasicus	5/9	1.6/2.9	50.5-55.2 52.73±0.22	60.3-70.1 63.36±0.24	30.3-32.0 31.28±0.16	30.8-31.4 31.25±0.11	6.0-6.6 6.28±0.02	6.1-6.4 6.27±0.02

Note: in the numerator – min-max, in the denominator – M±m.

Morphometric characters of scorpions: total body length (Tot.L) – length from the anterior edge of the carapace to the tip of the aculeus; metasomal length (Met.L) – from the anterior edge of the 1st metasomal segment to the tip of the aculeus; carapace length (Car.L) – the greatest distance between the anterior and posterior edges of the carapace – were measured directly on living or dead scorpions and on their discarded exoskeletons (exuvium). The measurements were carried out using a digital caliper under a light binocular microscope (MBI-6) with an accuracy of 0.01 mm; the mass (weight) was determined using electronic scales (Constant 14192-134C) with an accuracy of 0.001g. Each individual was weighed and measured before and after each moult, as well as at the imago+ stage. The sex of the juvenile scorpions was determined by examining the genital operculum on their exoskeletons under microscope: in males, their operculum are separate, while in females, they are fused. To estimate the individual growth of nymphs, two formulas were used: 1) the specific growth rate based on the change in weight $SGR_W = (\ln W_2 - \ln W_1) \times 100/\Delta t$, where SGR_W is the specific growth rate over the period Δt; W_1 and W_2 are the weights of animals at the beginning and end of the period Δt (respectively); 2) the specific rate based on the change in linear dimensions $SGR_L = (\ln L_2 - \ln L_1)/(t2 - t1)$, where SGR_L is the specific linear growth rate over the period t; L_1 and L_2 are the linear parameters of animals at the beginning and end of the growth period, respectively. The relative weight gain of nymphs was calculated using the formula: $P_W = (P_2 - P_1)/0.5(P_1 + P_2)$, where P_W is the relative weight gain; P_1 is the body weight of nymphs after each moult; P_2 is the body weight of nymphs after the next moult. The body weight to body length ratio of scorpions was calculated using the formula: $I_{W/L} = (W/L^2) \times 100$, where $I_{W/L}$ is the body weight to body length ratio; W is body weight, and L^2 is the squared body length. The severity of sexual dimorphism was assessed by calculating the dimorphism index (SDI) for each trait (mean values were used) using the formula: $SDI = [(X_2 - X_1) / X_1] \times 100$, where X_2 and X_1 are the mean trait values for males and females. Unlike other sex comparison indices, the dimorphism index is little dependent on sample size. Reproductive (biotic) potential – an indicator of the maximum possible productivity of a female during her lifetime – was calculated using the formula: $RP = \Delta N/N_0 \times \Delta t$,

where RP is the biotic potential; N is the total number of births; N_0 is the number of litters; t is the lifespan of the female. Statistical calculations and charting were performed in Excel 2010 and PAST 4.03 (Hammer *et al.*, 2001).

Results and Discussion

Growth duration. The ontogenesis of scorpions, like many other multicellular animals, includes embryonic and direct post-embryonic development, but differs from many terrestrial arthropods in some features of the reproductive cycle (the ritual of courtship of males for females before mating, viviparity, care of offspring, etc.) (Gould, 1977; Lourenço, 2018). Embryonic development in most Buthidae lasts from several months to a year or more, sometimes up to 18 months, and occurs within follicles in the ovaries of females. Post-embryonic development in scorpions spans the period from birth to adulthood (imago) (Polis, 1990; Benton, 2001). Scorpions of the family Buthidae have varying durations of post-embryonic ontogenesis. Among them, representatives of the genera *Lychas*, *Isometrus*, and *Centruroides* develop and reach to adulthood faster (6-8 months). Many representatives of the genera *Parabuthus* and *Grosphus* and some species of the genus *Tityus* are among the slowest growing (nearly 2.5 years). Representatives of the genera *Androctonus*, *Hottentotta*, *Leiurus*, *Buthus*, and *Mesobuthus* have an average duration of post-embryonic ontogenesis (nearly 1.5 years) (Francke, 1982; Polis & Sissom, 1990; Lourenço, 2018). It can be roughly divided into three stages: larval, nymphal, and imaginal. This classification is non-standard, but convenient for describing the results of our research. The larval stage is the shortest and lasts from the moment the newborn emerges until the first moult. The nymphal stage begins immediately after the first moult and includes a variable number of moulting stages, ranging from 5 to 12 in different species (more often 6-7). However, differences in the number of moulting stages can also be observed within a single species (Lourenço, 1979; Polis & Sissom, 1990). The duration of the different instars depends on the scorpion species and environmental factors (temperature, humidity, nutrition) in its habitat. The duration of the imaginal stage can also vary (from 2-3 to 5-6 years), during which scorpions can time and again produce offspring (Brown, 1997).

The duration of pregnancy in females of *M. eupeus*, according to various sources, ranges from 6.5 to 8 months, and in females of *O. caucasicus* – about a year. The duration of pregnancy in these species of scorpions varies depending on feeding and maintenance conditions (mainly temperature) (Yusubov, 1984; Vakhrushev, 2002). Some authors provide data on 12 months of gestation for *M. eupeus* (Malinina, 1981). According to our data, the gestation period varies greatly for each female and ranges from 4.5 to 9 months. In some cases, abrupt temperature fluctuations or disruptions to the feeding schedule extended the gestation period by an additional 2-3 weeks. Therefore, it can be assumed that, on average, gestation in *M. eupeus* lasts 6.5 months, and in *O. caucasicus*, 9 months. Parturition can last from one to two hours to several hours. After emerging from the female's genital pore, the larvae immediately shed their amniotic and serous membranes and ascend to the female's back. Unlike the nymphs and adult scorpions, newborns (larvae) are translucent and have milky-white or yellowish-white in colour and approximately 8-10 mm in total length. The number of newborns can vary (according to our data) from 14 to 56, depending on the scorpion species and the age of the female. After climbing onto the mother's back, the larvae remain there for 10-14 days. On the tenth to twelfth day, without leaving the mother's back, the larvae begin to moult almost simultaneously. After this initial moult, the larvae become nymphs, and their colouration becomes more similar to that of adult scorpions. About two-three days after

moulting, the nymphs begin to leave the mother's back one by one. From this point on, we began monitoring their growth and development, recording their size, and weight until they reached adulthood. During the first two weeks, we did not separate the *M. eupeus* nymphs, as previous observations showed that during this period of life, they retain a "group effect" (or Allee effect) (Allee & Bowen, 1932; Vakhrushev, 2002), which apparently stimulates their trophic activity and has a beneficial effect on development. However, closer to the second moult, separating the nymphs becomes advisable, as they may begin to exhibit cannibalism. In the scorpion *O. caucasicus*, nymphs should initially be kept singly, as cannibalism appears earlier and is more pronounced.

Linear growth dynamics and body weight changes. The linear growth dynamics and weight changes of scorpions were monitored throughout post-embryonic ontogenesis (larva → nymphs I-VI → imago+). At the larval stage, juveniles lacked claws and spurs on their legs, as well as trichobothrium and hairs on their body and limbs. All these characters began to appear after the first (I) or second (II) moult and were fully developed by the fourth (IV) nymphal stage. The period of juvenile development from birth (larval stage) to the completion of the I moult (nymph I) was characterized by low growth dynamics and weight changes (Table 2).

Table 2. Linear parameters (mm) and weight (g) at different stages of post-embryonic ontogenesis of *Mesobuthus eupeus* and *Olivierus caucasicus*.

Parameter		Instar					
		I	II	III	IV	V	VI
Weight	min-max	0.012-0.022 0.045-0.078	0.030-0.055 0.080-0.125	0.065-0.074 0.135-0.205	0.125-0.250 0.390-0.470	0.430-0.490 0.490-1.560	0.950-2.250 1.590-2.290
	M±m	0.020±0.0 0.064±0.01	0.040±0.0 0.100±0.02	0.070±0.01 0.161±0.03	0.190±0.09 0.423±0.03	0.460±0.02 1.196±0.43	1.540±0.15 1.950±0.21
Tot.L	min-max	11.01-16.20 11.07-17.30	19.20-23.03 18.15-22.05	23.09-24.60 22.08-25.09	23.90-27.50 26.06-29.50	36.55-47.20 37.60-49.20	39.31-53.80 49.38-56.79
	M±m	13.61±3.67 14.19±4.41	21.12±2.71 20.10±2.76	23.84±2.48 23.59±2.13	25.70±2.55 27.78±2.43	41.88±7.53 39.40±1.13	46.55±1.25 49.49±1.31
Met.L	min-max	6.11-8.08 6.15-10.50	10.06-13.87 11.06-15.09	13.35-15.87 15.90-17.80	13.67-16.35 17.81-18.45	17.28-21.70 19.24-22.08	21.23-27.29 22.23-28.76
	M±m	7.10±1.39 8.32±3.08	11.96±2.69 13.07±2.85	14.61±1.78 16.85±1.34	15.01±1.90 18.13±0.45	19.49±3.13 20.66±2.01	24.26±4.29 25.50±4.62
Car.L	min-max	0.80-1.61 0.90-1.72	1.10-1.80 1.20-1.92	1.50-2.11 1.81-2.30	2.30-2.60 2.91-3.12	2.80-3.30 3.21-3.50	3.81-4.53 4.20-4.72
	M±m	1.48±0.01 1.50±0.01	1.72±0.02 1.75±0.01	1.98±0.02 2.02±0.01	2.59±0.04 3.06±0.02	3.14±0.02 3.34±0.02	4.36±0.03 4.58±0.05

Note: I-VI – stages of nymphs development; in the numerator *Mesobuthus eupeus*, in the denominator *Olivierus caucasicus*.

In terms of the duration of development, *M. eupeus* nymphs were ahead of *O. caucasicus* nymphs: by 4-18 (9.2±2.8) days in early post-larval ontogenesis (I-III) and by 9-22 (15.0±3.5) days in late post-larval ontogenesis (IV-VI) (Fig. 1). A possible reason for this is the different requirements of these species for their living conditions. As is known, *M. eupeus* in the Lesser Caucasus lives mainly in rodent burrows or under big stones far from objects of human activity. The *O. caucasicus*, on the contrary, is predominantly a synanthropic species and chooses a variety of shelters located in close proximity to human dwellings and economic objects in rural areas and on the outskirts of cities (Yusubov, 1984). The initial sizes of *M. eupeus* nymphs varied within the range of 11.01-16.20 mm (Tot.L); 6.11-8.08 mm (Met.L); 1.42-1.48 mm (Car.L); weight within the range of 0.012-0.022 g. The sizes of *O. caucasicus* nymphs were 11.07-17.30 mm

(Tot.L); 6.15-10.50 mm (Met.L); 1.47-1.50 mm (Car.L); weight within the range of 0.045-0.078 g.

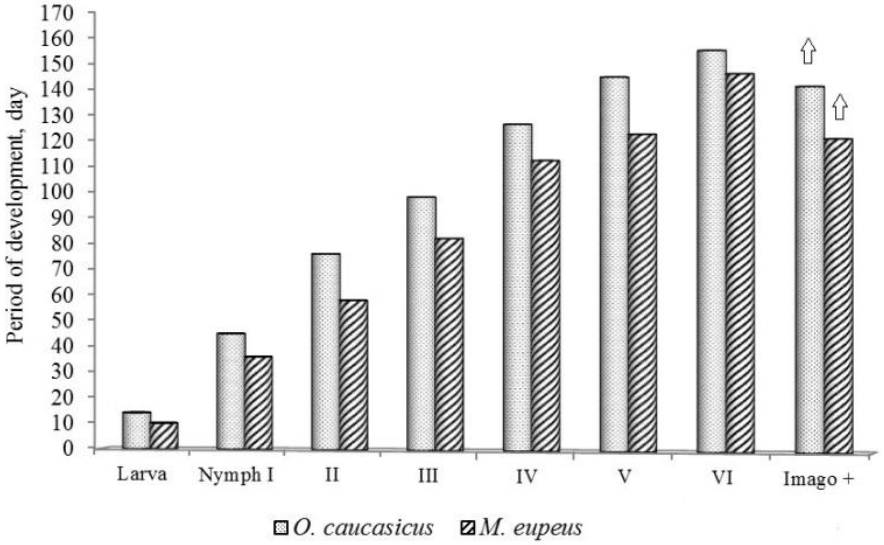

Fig. 1. Duration of developmental stages in post-embryonic ontogenesis of *Mesobuthus eupeus* and *Olivierus caucasicus*.

The linear parameters and body weight of young scorpions increased throughout post-embryonic ontogenesis, but showed significant differences at different stages of growth, accelerating at the beginning of each cycle and decelerating toward the end. It should be noted that the curves for changes in linear dimensions and weight on graphic do not reflect the growth rate, much less the growth intensity, which will be discussed separately. A feature of scorpion linear growth is that it occurs both during moulting and in the intervals between moults (intermoult) (Fig. 2). If growth over the entire cycle (from moult to moult) is taken as the unit whole, then growth during the moulting period accounts for approximately 4/5, and during the intermoult period, about 1/5. Conversely, body weight increases during the intermoult periods and remains constant or even decreases during moulting.

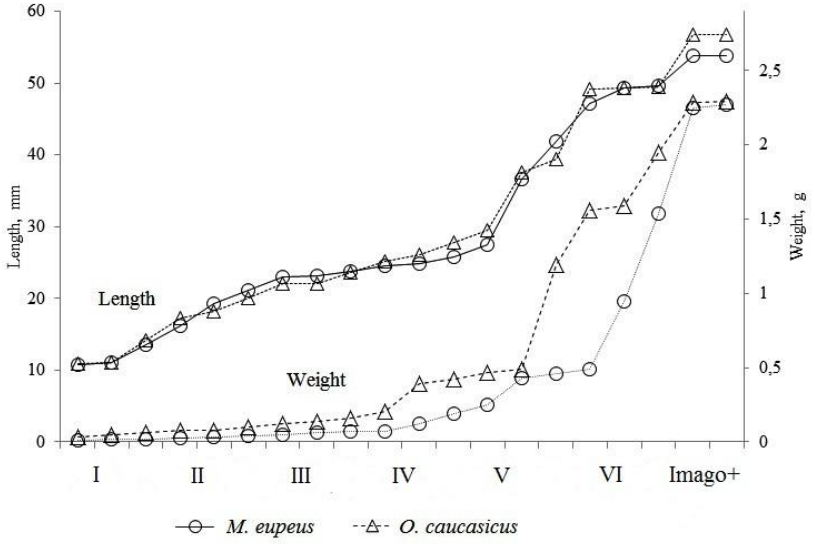

Fig. 2. Dynamics of changes in length and weight during the growth of the offspring of *Mesobuthus eupeus* and *Olivierus caucasicus*.

Statistical analysis revealed a weak positive allometric relationship between the carapace length (Car.L), total body length (Tot.L) and metasoma length (Met.L) in both scorpion species in the first half of the nymphal growth stage (I-III) (Fig. 3). Differences in the correlation of morphometric traits in the first half of the nymphal growth stage (I-III) in both species are statistically insignificant ($p > 0.05$; $p > 0.1$), in the second half of the nymphal growth stage (IV-VI) the relationships between the Met.L-Car.L traits are significant in both species ($r = 0.571$; $p < 0.05$); relationships between the Tot.L-Car.L and Tot.L-Met.L traits are significant only in *O. caucasicus* ($r = 0.591$; $p < 0.05$) (Table 3).

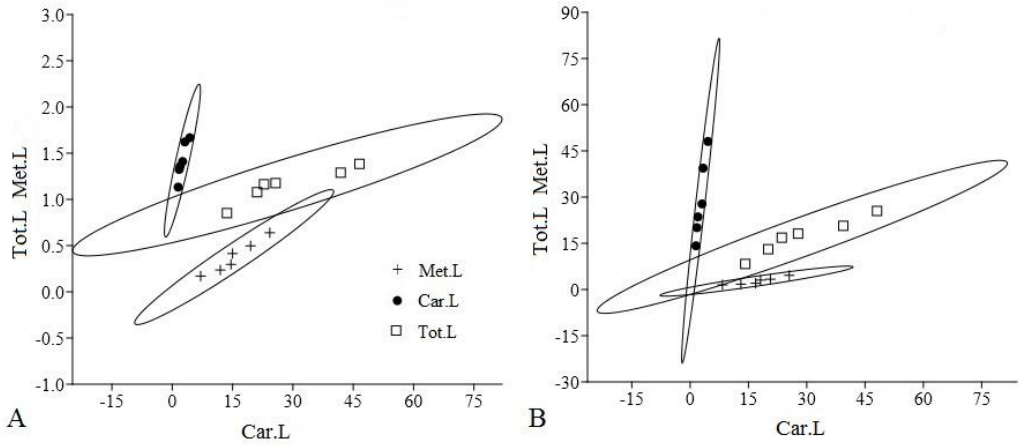

Fig. 3. Graph of the dependence of metric traits: carapace length (Car.L) on the total body length (Tot.L) and metasomal length (Met.L) in *Mesobuthus eupeus* (A) and *Olivierus caucasicus* (B).

Table 3. Correlations of linear growth parameters of nymphs of *Mesobuthus eupeus* and *Olivierus caucasicus*.

Species	Compared parameters (x, y)	Stage	Correlation coefficient (r)	Determination (R^2)	t	p
Mesobuthus eupeus	Tot. L – Car. L	I-III	0.458	21.0%	1.62	$p > 0.05$
		IV-VI	0.329	10.9%	0.813	$p > 0.1$
	Tot. L – Met. L	I-III	0.080	0.6%	0.25	$p > 0.1$
		IV-VI	0.188	3.5%	0.840	$p > 0.05$
	Met. L – Car. L	I-III	0.571	32.6%	2.20	$p > 0.1$
		IV-VI	0.571	32.6%	2.036	$p < 0.05$
Olivierus caucasicus	Tot. L – Car. L	I-III	0.376	14.1%	1.28	$p > 0.1$
		IV-VI	0.710	50.5%	3.194	$p < 0.05$
	Tot. L – Met. L	I-III	0.112	1.3%	0.35	$p > 0.1$
		IV-VI	0.933	87.1%	8.211	$p < 0.05$
	Met. L – Car. L	I-III	0.102	1.1%	0.32	$p > 0.1$
		IV-VI	0.591	34.9%	2.317	$p < 0.05$

The total duration of post-embryonic ontogenesis in *M. eupeus* averaged 18.8±0.47 months, while in *O. caucasicus* it was 21.9±0.41 months. The duration of developmental stages varied from 10 to 145 (63.7±11.4) days in *M. eupeus* and from 14 to 154 (74.7±12.5) days in *O. caucasicus*. By comparison, in the wild, the growth and development of these two species from birth to adulthood, according to literature data, occurs over a longer period of time – from 3 to 5 years, respectively – depending on the

local climate (Yusubov, 1984). When specifying the duration of ontogenesis, the author likely took into account that scorpions undergo a period of diapause lasting 4-5 months annually. The shortened developmental time of scorpions in laboratory populations may be explained by the absence of diapause periods and a more comfortable temperature and feeding regime. It should be noted that true winter diapause in scorpions apparently does not exist (Cloudsley-Thompson, 1988). However, according to Yusubov data and our observations in the natural conditions of the Lesser Caucasus, winter diapause in scorpions is expressed in their movement from surface shelters to deeper shelters (up to 30-40 cm from the soil surface), a sharp decrease in locomotor activity and a complete absence of trophic activity (Yusubov, 1984).

Sexual dimorphism in the growth process begins to appear in scorpions after the first (nymphal) moult, manifesting itself in the faster development of females compared to males. Females were ahead of males in each development cycle by an average of 2.63±0.53 days (*M. eupeus*) and 3.25±0.56 days (*O. caucasicus*). In both scorpion species, dimorphism for the Tot.L and Met.L traits were greatest at growth stages I and II, as well as at V and VI stages (Fig. 4). The highest dimorphism index values in *M. eupeus* and *O. caucasicus* scorpions for the Tot.L trait were 47.13% and 56.27%, respectively, and for the Met.L trait – 37.87% and 70.73%, respectively. Visually, this first became noticeable in nymphs immediately after the second moult. At moulting stages III and IV, the results of nymph size variability did not reveal pronounced dimorphism ($p > 0.05$). Dimorphism for the Car.L trait was weak at all growth stages (average 7.97% and 11.32%, respectively). Of the traits studied, two are clearly significant for sexual dimorphism in scorpions: greater metasomal length (Met.L) in males and greater total body length (Tot.L) in females. Dimorphism was also evident in the scorpions' lifespan and the number of moults. Males did not moult after reaching sexual maturity, while some sexually mature females went through two-three additional moults. The absence of additional moults in males is obviously associated with their shorter lifespan.

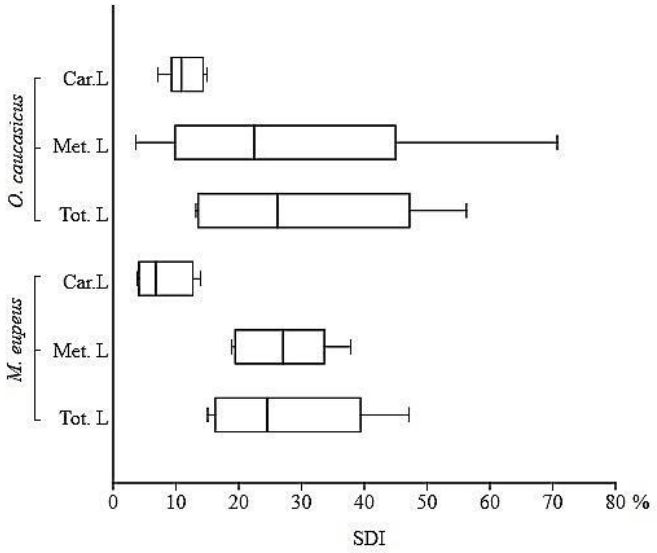

Fig. 4. Sexual dimorphism index (SDI) for linear traits (Tot.L, Met.L, and Car.L) in the offspring of *Mesobuthus eupeus* and *Olivierus caucasicus* during their growth period.

The average specific rate of linear growth of young scorpions had a pronounced cyclical: from the larval stage to the nymph stage I after the first (nymphal) moult this index was 0.430 (*M. eupeus*) and 0.333 (*O. caucasicus*); after the II moult – 0.856 and 0.967, and immediately after the III moult – 0.134 and 0.227 (respectively) (Fig. 5). This

indicates that the activation of growth of young scorpions begins after I and especially after the II moult. The decrease in this indicator after the III moult coincide with the period of decreased feeding activity (about a month) and chronologically corresponded to the period of diapause present in these species in the wild. Further increase in the average specific growth rate occurred until the completion of the IV moult (0.478 and 0.359) and began to decrease after the V moult (0.096 and 0.220, respectively). After completion of the VI moult, the average specific growth rate was only 0.021 (*M. eupeus*) and 0.062 (*O. caucasicus*). The average specific growth rate based on body mass change in both scorpion species was also cyclical and was highest after I, II, and IV moults. This indicator had low values after III, V, and VI moults.

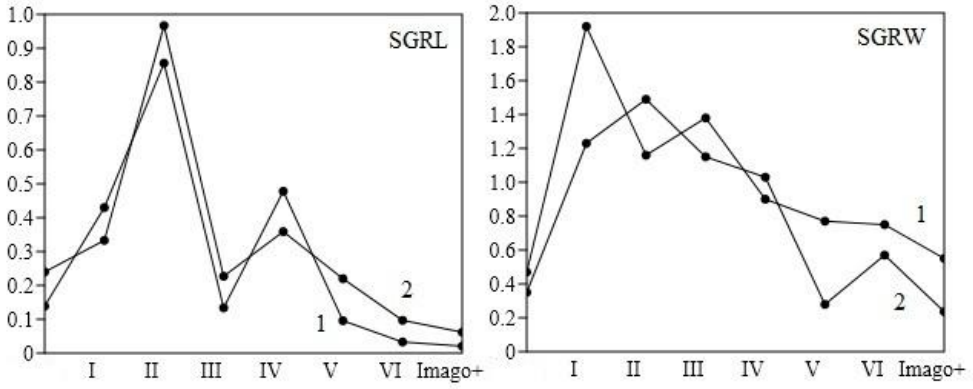

Fig. 5. Changes in the indices of linear growth and weight gain during ontogenesis of *Mesobuthus eupeus* (1) and *Olivierus caucasicus* (2).

From birth (larval stage) to the completion of the first moult (nymphal stage), juvenile scorpions did not feed, using the nutrients remaining after hatching. Their feeding activity began to manifest itself only 9-12 days after first moult. Therefore, the relative weight gain (P_W) between the first and second moults was only 0.462 (*M. eupeus*) and 0.540 (*O. caucasicus*). During the development period from the completion of the second moult to the beginning of the third moult, nymphs actively fed, and a significant increase in P_W was observed: 0.595-0.782 (*M. eupeus*) and 0.541-0.711 (*O. caucasicus*). After the fourth moult, the increase in the nymphs' body weight was already 0.812 and 1.043 (respectively). During the transition to the pre-imago stage (the fifth moult) and after reaching the imago stage (the sixth moult), the increase in the scorpions' body weight decreased and was 0.668-0.195 and 0.407-0.186 (respectively). The overall picture of the dynamics of linear growth of *M. eupeus* and *O. caucasicus* nymphs was largely similar, and the increase in mass in *O. caucasicus* nymphs occurred faster.

The dynamics of index body weight to length ratio ($I_{W/L}$) may indirectly indicate changes in metabolism during the growth process. It was found that the body weight to length ratio ($I_{W/L}$) changes unevenly throughout the entire period of postembryonic ontogenesis in scorpions (Fig. 6). Up to the fourth moult, scorpions exhibit more intensive linear growth, especially in *O. caucasicus*. With further development (after the IV moult), body weight increases faster – 0.812 and 1.043 (respectively). The index of body weight to linear size ratio was high in the period from the IV to the VI moult (0.739-3.308 and 1.522-4.054, respectively). The average body weight to linear size ratio for all age groups studied was 0.964±0.08 (*M. eupeus*) and 1.706±0.16 (*O. caucasicus*).

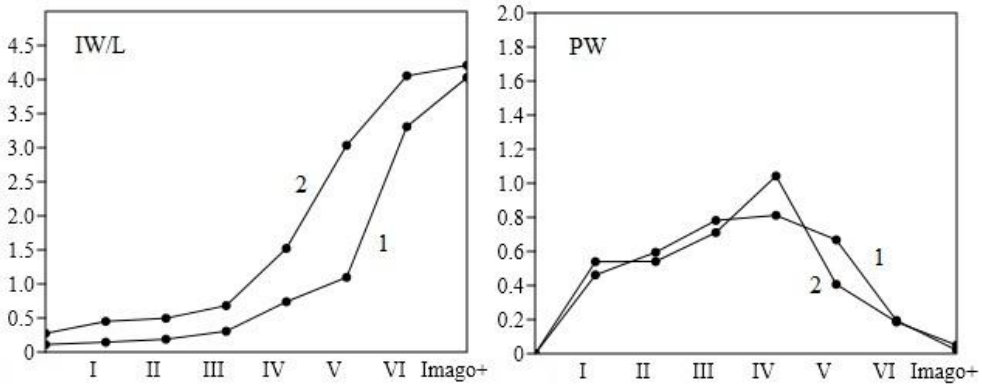

Fig. 6. Changes in the indices of body weight to length ratio and relative weight gain during ontogenesis of *Mesobuthus eupeus* (1) and *Olivierus caucasicus* (2).

In the early stages of development, young scorpions rapidly gain weight before moulting, and immediately after moulting, accelerated linear growth begins. This process, more intense in *O. caucasicus*, provides them with the increased activity necessary for normal functioning in challenging anthropogenic conditions (concern factors and food shortages). Closer to sexual maturity (imago), the rate of linear growth remains dynamic, and weight gain in both species remains virtually unchanged. The biological rationale for weight gain and accelerated linear growth in early development is clearly the desire to quickly reach sexual maturity, acquire reproductive capacity, and resist potential predatory pressure.

If we consider the life cycle of scorpions, conditionally dividing it into two periods – before and after the imago stage – then it is obvious that the differences in growth rates in the first period of the life cycle are more pronounced than in the second. This is likely due to the more pronounced trophic activity and greater similarity in the qualitative composition of food in immature individuals compared to mature individuals. Based on the presented data, it can be assumed that the different dynamics of changes in the body length-to-weight ratio are also due to their different reproductive potential during the breeding process. According to our data, *M. eupeus* females (n = 28) produce more offspring per season (12-52, on average 26±0.55) than *O. caucasicus* (n = 19) (8-38, on average 14.7±0.34). Yusubov E.B. provides slightly different data for the Lesser Caucasus populations: 24-42 juv. for *M. eupeus*, and 34-42 juv. for *O. caucasicus* (Yusubov, 1984). However, author does not indicate the number of females on which his data is based. It should also be taken into account that while the female is carrying her litter on her back, accidental losses of 5.5 to 9.6% cubs are possible (according to our data). Therefore, the original litter size was almost certainly somewhat larger than the author's estimate. According to our data, the reproductive (biotic) potential (RP) in laboratory conditions for *M. eupeus* females is 6.11–8.66 (n = 11), and for *O. caucasicus* females is 3.51–5.42 (n = 9).

Changes in nymph growth and weight from first to third moults were moderately exponential, apparently related to unlimited food resources (in captivity) and periodic moults that conventionally divide their development into instars. However, begin with IV moult moderately exponential growth gives way to logistic growth, which is apparently genetically determined by the need to stabilize overall developmental dynamics (the interaction between growth rates and limiting factors). This growth pattern is apparently initially associated with relatively favourable conditions of artificial maintenance and regular feeding of nymphs, which in natural conditions is most likely unlikely due to the

influence of various abiotic and biotic environmental factors, as well as limited or difficult to access food resources.

During early post-larval ontogenesis of nymphs (I-III), the specific growth rate and mass gain tend to steadily increase. During late post-larval ontogenesis of nymphs (IV-VI), the specific growth rate and mass gain gradually decrease. This occurs in the form of small fluctuations in these parameters over periods of time of varying duration: on average 26.4±1.16 days (*M. eupeus*) and 38.0±1.04 days (*O. caucasicus*).

Growth rate and intensity. The growth rate is characterized by the absolute value of linear growth and mass gain, and the growth intensity is characterized by the multiplicity of increase in these parameters. As individuals develop, growth rate increases up to a certain age, while growth intensity increases in the early stages of development and declines in the second half of development. In this case, dynamic growth parameters, such as the specific rate of linear growth and the specific rate of mass increase, are considered as the difference in their ratio, divided by *b*, where *b* is a constant equal to three, since scorpions undergo direct development with the maintenance of geometric similarity during growth. For those species that change geometric similarity (indirect development), the constant is equal to four (Soper & Smith, 1979). The growth rate of *M. eupeus* varies little from birth (larval stage) to the first moult (nymphal stage I). However, as development proceeds after the first and especially the second moult, this value increases from 0.10 to 0.28. This increase is not constant, which is probably due to a decrease in metabolism during moulting periods. An increase in the growth rate is observed between the first and second, third and fourth, and fourth and fifth moults, averaging 0.586±0.001. The maximum values of this parameter were recorded in *M. eupeus* between III and IV moults, and in *O. caucasicus* between IV-V and V-VI moults. Subsequently, as the scorpions developed (V-VI moults and imago+), the specific growth rate decreased slightly, but remained higher than the initial values (*M. eupeus*). With increasing age, one year after reaching sexual maturity, the growth rate continued to decrease. The growth rate of *O. caucasicus* in early post-larval ontogenesis until the completion of the third moult fluctuated within 0.10-0.15. Only after the third moult did this indicator reach high values (0.8-0.81), and at the remaining stages of late post-larval development (IV-VI moults) it decreased, varying between values of 0.39-0.23.

The process of post-embryonic growth of poikilothermic animals can conditionally include several phases: no growth, linear growth, exponential growth, parabolic growth, and a phase of growth degradation (Vinberg, 1975). The growth rate of scorpions can similarly be divided into several phases sequentially replacing each other. Then the phase of no growth can be tied to the larval stage, which lasts from birth to the first moult; the exponential growth phase is observed after the second and third moults; the parabolic growth phase is traced between the third-fourth and fourth-fifth instars. The linear growth phase is observed after the completion of almost every moult. And, finally, the phase of growth degradation takes place at the very last stage – Imago+. In each of the indicated growth phases, a change in the ratio of weight and linear parameters was noted: towards a decrease during the moulting period and an increase immediately after the completion of moulting.

The growth intensity (GI) is the ratio of the difference between the current (GR_n) and previous (GR_{n-1}) growth rate to the previous growth rate. The growth intensity of scorpions was highest in *M. eupeus* nymphs in length at the II-IV instars, and in weight at the I-III instars; in *O. caucasicus* in length at the II-III instars, and in weight at the I-IV instars.

Changes in growth intensity (in linear dimensions and mass) were observed throughout the development of nymphs, decreasing during moulting and increasing

between moults. During the last (VI) moult, the scorpions showed a minimum growth rate of 0.035±0.01 in length and 0.64±0.05 in weight (*M. eupeus*); 0.07±0.01 in length and 0.38±0.01 in weight (*O. caucasicus*). After completion of the last moult and reaching the imago stage, the growth rate decreases to approximately three times of the initial value. Consequently, in early post-larval ontogenesis (nymphs I-III), the growth rate and growth intensity tend to steadily increase. In late post-larval ontogenesis (nymphs IV-VI), the growth rate and growth intensity gradually decrease. All this occurs against a background of constant fine-frequency fluctuations in these parameters with varying durations: on average, 26.4±1.16 days (*M. eupeus*) and 38.0±1.04 days (*O. caucasicus*).

Thus, during scorpion's ontogenesis, maximum growth intensity was observed only in the early nymphal stages, and minimum growth was observed at the imago+ stage (Fig. 7). In addition, nymphs of both species showed some decrease in growth rate and weight gain during periods of no feeding activity before moulting and during periods chronologically coinciding with their natural diapause that occurs from October-November to March in wild. As is known, diapause in arthropods in nature is regulated by temperature and photoperiod (Denlinger, 2002). In our experiment, the temperature regime and photoperiod changed slightly with the changing seasons. Consequently, the regulator of the diapause could have even been a partial decrease in temperature by 5-6ºC and/or a reduction in the photoperiod in the autumn-winter period, since only natural lighting and general heating were used in the room where the scorpions were kept.

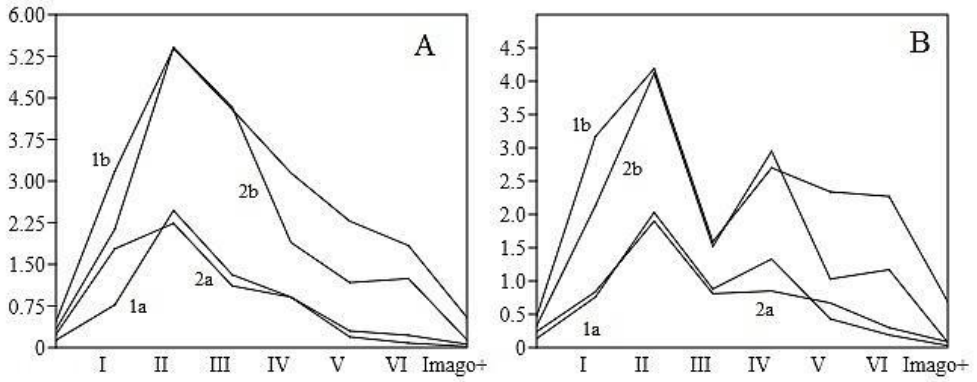

Fig. 7. Growth rate and growth intensity by length and weight during the ontogenesis of *Mesobuthus eupeus* (A) and *Olivierus caucasicus* (B). Note: 1 – growth rate; 2 – growth intensity; a – length; b – weight.

An analysis of the relationship between the specific growth rate (SGR_L) and specific body mass gain (SGR_W) in scorpions showed that in both species the specific growth rate is more or less dependent on changes in body mass. Data for each of these parameters, obtained for different developmental stages, were positively correlated (r = 0.456-0.733). The strength of the correlations between specific growth rate and body weight gain varied at different stages of ontogeny. This is likely due to the specific functioning of organs and systems at a given stage of development, as well as changes in the rate and direction of metabolic processes (Vinberg, 1975).

To identify sexual dimorphism in the dynamics of changes in the main growth parameters (SGR_L, SGR_W) and growth duration (GD) a linear regression model was used with the calculation of the constant (Intercept), regression coefficients (β) and determination (R^2) (Table 4).

The regression coefficient (β) had positive values for all parameters, indicating unidirectional changes in the parameters under consideration for males and females of both species. The model constant (Intercept), having positive values for SGR_L in both

species, may indicate that changes in growth parameters in females of these species are more dynamic. Negative values of the constant observed for GD in both species and SGR_W for *O. caucasicus*, conversely, indicate more dynamic changes in parameters in males (Teder & Tammaru, 2005). The coefficient of determination (R^2) was also considered in the analysis of the material as the primary indicator reflecting the quality of the regression model describing the relationship between the dependent and independent variables.

Table 4. Results of regression analysis of the dynamics of changes in linear parameters (SGR_L), body weight gain (SGR_W) and growth duration (GD) in males/females.

Statistical indicator	GD		SGR_L		SGR_W	
	1	2	1	2	1	2
Slope (b_1)	0.9835	0.998	0.9253	1.1767	0.2601	4.2277
Intercept (b_0)	-1.2117	-3.048	0.0546	21.015	61.9132	-0.7287
Regression Line Equation	Y = -1.2117 + 0.9835X (1)		Y = 0.0546 + 0.9253X (1)		Y = 61.9132 + 0.2601X (1)	
	Y = -3.048 + 0.998X (2)		Y = 21.015 + 1.1767X (2)		Y = -0.7287 + 4.2277X (2)	
(β)	0.9997	0.9996	0.9391	0.8722	0.5021	0.9527
(R^2)	0.9994	0.9991	0.8819	0.7607	0.2521	0.9076
p-value	0.0	0.0	0.0054	0.0047	0.0962	0.0003
Standard Error	0.0101	0.0119	0.1693	0.2694	0.1416	0.5508

Note: (β) - Regression Coefficient; (R^2) - Determination Coefficient;
(1) – *Mesobuthus eupeus*; (2) – *Olivierus caucasicus*.

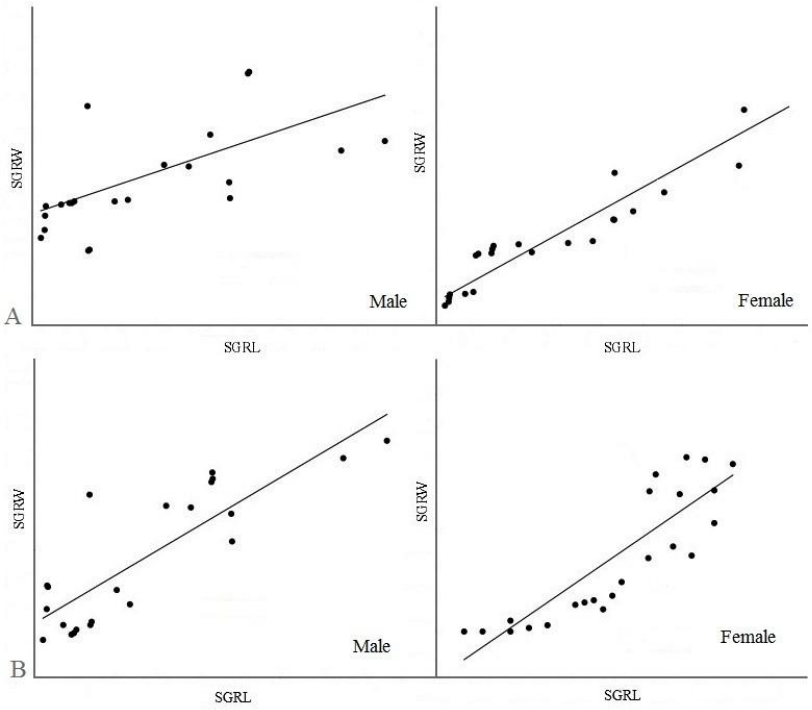

Fig. 8. The relationship between the specific linear growth rate (SGR_L) and the weight gain (SGR_W) in males and females of *Mesobuthus eupeus* (A) and *Olivierus caucasicus* (B).

As can be seen from the table (4), the models describing the regression of growth and weight parameters in males and females satisfactorily demonstrate the studied pattern for all the studied parameters (regression coefficients 0.5021-0.9527; determination coefficients 0.2521-0.9076). The tendency that p-value of the determination coefficient

(R^2) to zero indicates a satisfactory quality of the models. Growth parameters (SGR_L, SGR_W) in both sexes (especially in *M. eupeus* females) change dynamically, with a slight predominance of growth parameters in *O. caucasicus* females. Positive values of the model constant (Intercept) in relation to SGR_L in both species indicate that females increase in size faster than males, i.e., female growth is more dynamic (Fig. 8). The adaptive significance of sexual dimorphism in the studied parameters with a predominance of one of the sexes, apparently, lies in their different roles in the reproductive function.

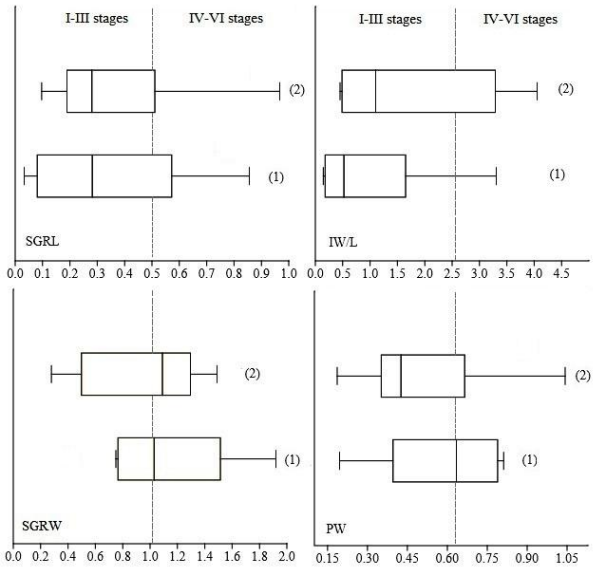

Fig. 9. Dynamics of the main growth indexes of *Mesobuthus eupeus* (1) and *Olivierus caucasicus* (2) on a box plot.

Comparative dynamics of changes in the main plastic and weight indices of growth of two species of scorpions complements an objective picture of the growth rates and overall stability of their development (Fig. 9). The data presented in the figure demonstrate that throughout post-embryonic ontogenesis, the rate of change in growth indices is quite dynamic, but uneven at all stages of development. Although growth processes occur continuously, their rate has a nonlinear dependence on the stage of development. A decrease in growth rates coincided with moulting periods, while an increase was observed between moults. Changes were particularly intense in the first half of post-larval ontogenesis (nymphs I-III), while in the second half (nymphs IV-VI) they decreased but remained moderately dynamic. Thus, from the standpoint of overall development, scorpion growth was primarily achieved through genetically determined growth mechanisms. Interspecific similarities and differences in the dynamics of growth rate changes occurred at the beginning and at the end of each growth period. The data presented in figure (9) also shows that the average growth rate of linear dimensions in *M. eupeus* was slightly higher than that of *O. caucasicus*. Conversely, weight gain was comparatively higher in *O. caucasicus*. Another one trend is evident in the data in the figure: the diagram of changes in the parameters under study shows an asymmetry in the medians and whiskers on the box plots, which may indicate an uneven data distribution or other factors, not accounted for during the study. It should also be taken into account that, despite the absence of diapause periods when keeping scorpions, a seasonal component may still be present, as it is inherent in both species under consideration in the climatic conditions of the Lesser Caucasus. In the conditions of Lesser Caucasus, the emergence of newborn scorpions occurs from late May to mid-July (Yusubov, 1984). Therefore, in

nature, from the moment of birth (July) until the onset of diapause (October-November), scorpions presumably manage to undergo two moults and overwinter until April at the instar of nymph II.

The obtained results indicate that the growth dynamics of *M. eupeus* and *O. caucasicus* vary at different stages of their development. During early post-larval ontogenesis, active increases in both body mass and length were observed. As scorpions increase in size, the breadth of their feeding spectrum increases and their feeding intensity decreases (Novruzov, 2021). As feeding intensity decreases, linear growth and mass gain slow down. However, there is an assumption, based on incompletely verified data that *M. eupeus* growth does not complete after reaching sexual maturity. Since we observed two additional moults (possibly facultative?) in adult *M. eupeus* females kept in laboratory conditions, which occurred approximately one year after the birth of the first and second offspring (Novruzov, 2018).

Scorpions are thought to have the lowest metabolic rate among arachnids (spiders, mites, solifuges) and that it varies with their sex, body size, locomotor activity, and ambient temperature (Hodley & Hill, 1969; Lighton *et al.*, 2001). The growth dynamics of living organisms may indirectly reflect the activity of energy metabolism through the interrelationship between growth and energy metabolism. Growth dynamics can indicate the characteristics of energy metabolism at different periods of ontogenesis (Kayumova *et al.*, 2021). Growth is accompanied by an increase in body mass and linear dimensions. It can be uneven, with periods of accelerated growth alternating with periods of deceleration. The energy expenditure on growth changes with age. Particularly high energy expenditure is typical for juveniles during the first half of post-larval development. However, even during periods of the most intensive growth, no more than 5% of daily energy intake is spent on this (Ozernyuk, 2000). During periods of slower growth, the body accumulates energy and plastic resources, and during periods of growth activation, these resources are directed toward intensive growth. During periods of slow growth, differentiation processes are also activated, determining the dynamics of the qualitative development of the organism and the intensity of the basal metabolism – those energy expenditures that are not directly related to the growth function. This likely explains why the body cannot accumulate the amount of energy and plastic resources necessary for continuous growth and development. However, females of some species of scorpions (Buthidae) and spiders (Nephilidae) are capable of growing throughout their entire ontogenesis, and not just until adulthood (Kuntner *et al.*, 2012; De Souza *et al.*, 2016). After reaching sexual maturity, they are capable of producing offspring 2-3 times and moulting the same number of times. In the wild (Lesser Caucasus), we occasionally encountered female *M. eupeus* and *O. caucasicus* scorpions of record sizes (69.5 mm and 87.6 mm, respectively), which presumably moulted several times after reaching adulthood. However, this is extremely rare, as scorpions rarely survive to old age in the wild for a number of abiotic and biotic reasons: unfavourable wintering conditions, injuries sustained during hunting, pressure from natural enemies, illness, prolonged lack of food and other reasons. The literature indicates the lifespan of these two species as 6 and 7 years, respectively (Yusubov, 1984). Under laboratory conditions, with proper care and moderate feeding, the lifespan of scorpions increases by at least 1-2 years for males and 2-3 years for females. For example, under our conditions, the maximum lifespan of female *M. eupeus* reached 8.5 years, and that of female *O. caucasicus* reached 10.8 years.

Conclusion

In a result four-year laboratory study of the reproductive activity of the scorpions *Mesobuthus eupeus* and *Olivierus caucasicus* revealed that the duration of pregnancy

varies greatly among females, averaging 6.5 months for *M. eupeus* and 9 months for *O. caucasicus*. The growth of young scorpions is uneven, with cycles lasting varying lengths: for *M. eupeus,* from larval stage to moult III is an average of 186 days, and from IV moult to VI moult (imago) is an average of 379 days; for *O. caucasicus*, the average is 233 and 424 days, respectively. Four-fifths of the entire growth cycle occurs during moulting, and the remaining one-fifth occurs during the intermoulting period. In terms of development rate, *M. eupeus* nymphs outpaced *O. caucasicus* nymphs in early post-larval ontogenesis (I-III) by an average of 9.2±2.8 days and in late post-larval ontogenesis (IV-VI) by an average of 15.0±3.5 days. Changes in growth rate and intensity tended to increase at the beginning of development and decrease at the end. Nymphs of both species also showed a decrease in growth rate and weight gain during periods of no feeding activity before moulting and during periods chronologically corresponding to their natural diapause in nature. In both scorpion species, a weak positive allometric relationship was revealed between changes in three linear traits: carapace length (Car.L), total body length (Tot.L), and metasomal length (Met.L) from nymphal growth stages I to III, and a moderate positive relationship from nymphal growth stages IV to VI. Sexual dimorphism was manifested in a faster growth rate, more dynamic changes in body size and weight, a greater number of moults, and a longer lifespan in females compared to males.

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Ethology, ecology and distribution of *Buthus apiatus* Lourenço, El Bouhissi & Sadine, 2020 in Algeria (Scorpiones: Buthidae)

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Abstract

Buthus apiatus Lourenço, El Bouhissi & Sadine, 2020 is an endemic scorpion species in Algeria, first discovered in the Sidi Bel Abbès region in the northwest of the country. It was previously thought to have a restricted distribution limited to Sidi Bel Abbès, Tissemsilt and Tiaret in western Algeria. However, recent field survey has revealed a wider range than previously assumed, with confirmed occurrence in several additional areas of western Algeria that extend to the central-eastern regions, including Tlemcen, Naama, Mascara, Saïda, Laghouat, Bayadh and M'Sila. These new records suggest a substantial expansion of the species known range, highlighting its broader ecological tolerance and potentially redefining its distribution limits. Furthermore, *B. apiatus* has been observed across diverse habitats in Algeria, demonstrating considerable ecological flexibility.

Keywords: *Buthus apiatus*, Ecological tolerance, Habitat diversity, Algeria.

Introduction

Buthus was first introduced by Leach in 1815, designating *Scorpio occitanus* Amoreux, 1789 as its type species. The sole diagnostic feature proposed by Leach was the presence of eight eyes, described as "*Oculi octo*" (Leach, 1815, p. 391), referring to one pair of central eyes and three pairs of lateral eyes. This characteristic was noted as a distinguishing feature for various scorpions in the early stages of Scorpiones taxonomy (e.g. De Geer, 1778 and Fabricius, 1781). *Buthus*, described by C.L. Koch in 1837 and again in 1850, is the type genus of family *Buthidae*. Within family, diversity reigns the Scorpiones order, encompassing nearly half of all known living scorpion species, with 1,301 out of 2,914 species (Rein, 2026). Genus *Buthus* is widely distributed across Africa, southern Europe, and the Middle East in Asia (Kovařík, 2006). In Algeria, the number of *Buthus* species has increased to 11 (Dupré *et al.*, 2023). *B. apiatus* is an endemic species of Algeria, first identified in Sidi Bel Abbès by Lourenço *et al.* (2020). It has also been recorded in Tiaret and Tissemsilt (Chedad *et al.*, 2022; Ait Hammou *et al.*, 2023). This species remains among the least studied, with insufficient studies conducted on its behaviour, habitat and physiological adaptations, this led us to study it, to update its distribution, to identify its different habitats, forest, steppe, maquis and even to analyze its behaviour.

Fig. 1. Different biotopes of *Buthus apiatus* in Algeria. A. forest. B-C. steppe. D. maquis.

Material and Methods

Scorpion samples were collected as part of a field study of the ecological diversity and geographical distribution of scorpions in Algeria, through several sampling campaigns between 2021 and 2025. During these surveys, specimens of *B. apiatus* were collected from various habitats including forests, plains, mountainous areas, and even

semi-arid systems. The specimens were then fixed and preserved in 70% ethanol. Specimens were identified under a stereomicroscope following methodology of Vachon (1974). The material is deposited in Ibn Khaldoun University of Tiaret, Algeria.

Results and Discussion

Systematics

Family ***Buthidae*** C.L. Koch, 1837

Genus ***Buthus*** Leach, 1815

Buthus apiatus Lourenço, El Bouhissi & Sadine, 2020 (Figs. 2-4)

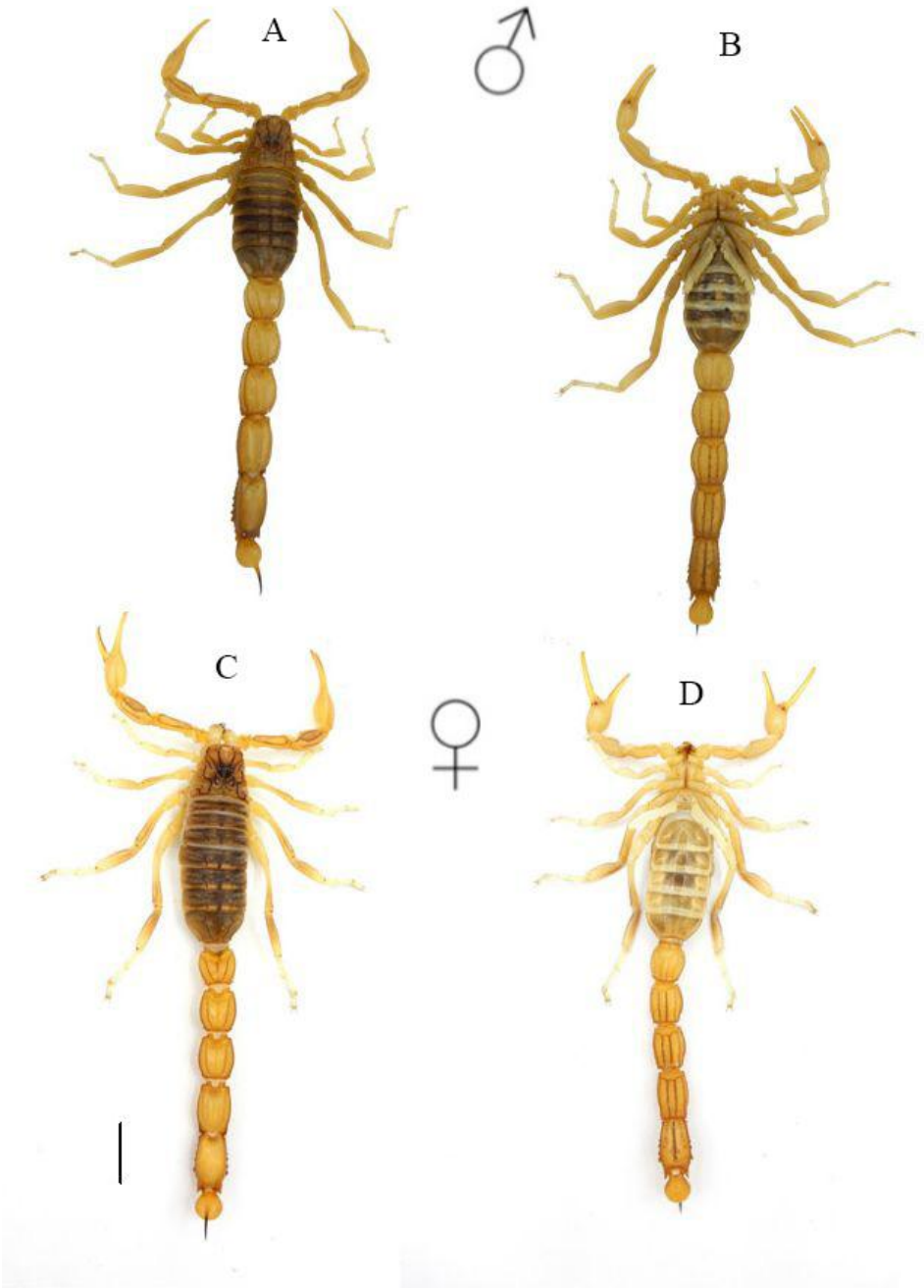

Fig. 2. *Buthus apiatus,* habitus. A, C. dorsal view. B, D. ventral view. (Scale bar: 10 mm).

Ecological aspects of the habitat and behavioural patterns

Buthus apiatus inhabits a variety of environments of hot, dry summers and relatively cold winters. This species appears to favour rocky areas, sandy-clay soils, and open habitats with sparse vegetation, such as steppes and hillsides (Chedad *et al.*, 2023; Ait Hammou *et al.*, 2023). Field observations indicate that it is a nocturnal species, becoming active mainly at dusk to hunt. Its activity patterns are influenced by temperature and relative humidity, with higher activity observed during warmer seasons. Like other members of family *Buthidae*, it exhibits cryptic behaviour during the day, seeking shelter under stones, in crevices, or beneath vegetation to avoid desiccation and predators (Lourenço *et al.*, 2020).

Fig. 3. *Buthus apiatus* mating and maternal care in Tiaret, north-western Algeria.
A. The mating took place at 21:49 on July 13, 2023, in Tiaret. A male and a female *Buthus apiatus* were observed engaged in a courtship dance, the male leading the female by grasping her pedipalpal fingers with his own. B. A female *Buthus apiatus* carrying scorplings on her back in Tiaret. This behaviour is typical after parturition, as the newborns climb onto the female's dorsum and remain there until their first moult, relying on maternal protection (Polis & Sissom, 1990)

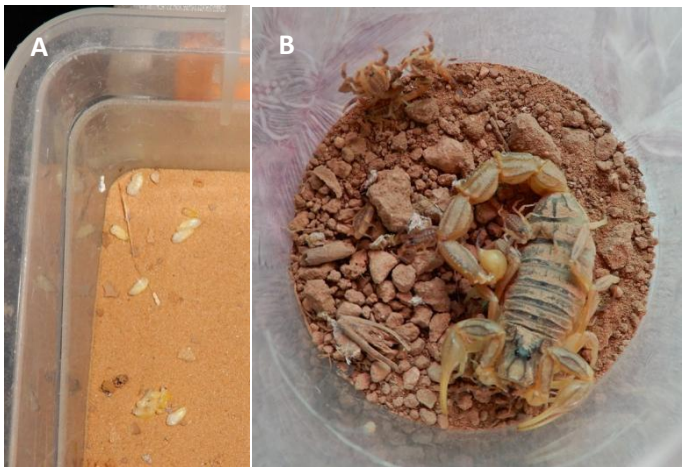

Fig. 4. *Buthus apiatus*. A. Stillborn larvae. B. Female and larvae in captivity.

During our field surveys, several gravid females of *Buthus apiatus* were collected and transferred to the laboratory, where they were kept under close observation and regularly fed. After a variable period of monitoring, parturition was observed in several

individuals, with the number of offspring ranging from 11 to 17 (Fig. 4A, B) while one female gave birth to 11 larvae, all of which died shortly after birth (Fig. 4B).

Fig. 5. *Buthus apiatus* exhibiting different predatory interactions in its natural habitat. A. predation on the praying mantis *Mantis religiosa*. B. predation on *Galeodes* sp. C. predation on the white grub. D. intraspecific predation on *Buthus* sp. E. predation on Lepidoptera caterpillar.

The diet of *Buthus apiatus*

Scorpions are key nocturnal predators in arid and semi-arid ecosystems, where they play an essential role in maintaining ecological balance by regulating populations of other arthropods (Polis, 1990; McCormick & Polis, 1990). Their diet is primarily composed of insects, spiders, and other small arthropods, although cases of intraspecific predation (cannibalism) have also been documented, particularly under conditions of food scarcity or high population density (Lourenço & Cloudsley-Thompson, 1996).

In Algeria, regarding the feeding ecology of scorpions, several studies have specifically focused on the genera *Buthus*, *Scorpio*, and *Androctonus* documenting their dietary behaviour and prey diversity in various natural environments (Chedad *et al.*, 2022; Sadine, 2024).

Despite its relatively wide range, *Buthus* remains poorly studied. There is a lack of comprehensive research on its ecological role, microhabitat preferences, reproductive behaviour, and physiological adaptations (Dupré *et al.*, 2023). Interestingly, *B. apiatus* has been observed as a nocturnal predator capable of preying on relatively large arthropods such as camel spiders (Solifugae). A notable example of this behaviour was reported in Tiaret, north-western Algeria, where an individual was seen capturing and feeding on a camel spider in its natural habitat (Benali *et al.*, 2024).

The predatory behaviour of *B. apiatus* was documented in several field observations, as illustrated in Fig. (5). This species was observed preying on different

arthropods and even engaging in intraspecific interactions. Specifically, individuals of *B. apiatus* were recorded capturing and consuming the praying mantis *Mantis religiosa* (Fig. 5A), the camel spider *Galeodes* sp. (Fig. 5B), preying on white grub, and cases of intraspecific predation cannibalism were also observed (Fig. 5D), in addition to predation on Lepidoptera caterpillar (Fig. 5E).

This diversity of prey indicates that *B. apiatus* exhibits an opportunistic feeding strategy that enables it to exploit the resources available in its arid environment. Predation on a wide range of arthropods reflects dietary flexibility, which represents an important adaptive trait in desert ecosystems characterized by food scarcity and unpredictability (Polis, 1990). Intraspecific predation, on the other hand, is a common behaviour in scorpions and is often associated with food limitation, competition for resources, or even population density regulation (Polis & Farley, 1979; Polis, 1981). Moreover, the ability to prey on relatively large predators such as *Galeodes* highlights the species' capacity to handle strong prey, underlining its behavioural and physiological efficiency as a key predator (McCormick & Polis, 1990).

Based on these observations, *B. apiatus* can be considered an important predator contributing to the dynamics of arthropod communities in arid ecosystems, by regulating prey populations and influencing local food web structures (Polis, 1991; Sánchez-Piñero *et al.*, 2025).

Geographical considerations and ecological distribution of *Buthus apiatus* in Algeria

Algeria encompasses a remarkable diversity of bioclimatic zones, ranging from the humid Mediterranean regions in the north to the semi-arid high plateaus and the hyper-arid Sahara in the south. This geographical variability strongly influences the distribution of scorpion species across the country. Within this framework, *B. apiatus* is predominantly associated with arid and semi-arid habitats, where it has adapted to harsh environmental conditions such as extreme temperatures, low humidity, and irregular food availability. Its presence across different ecological gradients highlights both its ecological plasticity and its role as a key predator in structuring arthropod communities in these environments (Polis, 1990; Lourenço, 2002; Sadine *et al.*, 2018).

In addition to *B. apiatus*, other species of the genus *Buthus* are also found across the Algerian Sahara. For instance, *Buthus saharicus* Sadine, Bissati & Lourenço, 2015 is widely distributed in hyper-arid desert habitats, demonstrating the genus ability to thrive under extremely dry conditions. Moreover, species such as *Buthus ahaggar* Ythier, Sadine, Haddadi & Lourenço, 2021 and *Buthus tassili* Lourenço, 2002 occur in the extreme southern Sahara of Algeria, including highly inhospitable environments. These records suggest that the genus *Buthus* exhibits a remarkable ecological plasticity, enabling its representatives to colonize a wide range of habitats from northern Mediterranean zones to the most arid Saharan regions. In this regard, *B. apiatus* follows the same ecological pattern, as it is present in different environments and shows considerable adaptability to diverse ecological conditions (Lourenço, 2002; Sadine *et al.*, 2018).

Based on systematic field surveys and the collection of specimens from different regions of Algeria, detailed laboratory analyses were conducted using specialized taxonomic and morphological methodologies. This integrative field-laboratory approach enabled us to accurately delineate the spatial distribution of this species within Algeria (Table 1), leading to the construction of a detailed map of its geographical range, as presented in Fig. (6).

Table 1. New observation points of *Buthus apiatus* in Algeria.

Province	Latitude	Longitude	Altitude (m)
Tlemcen	34°33'34.60"N	1°38'32.40"W	1220
Tlemcen	34°25'31.67"N	1°06'58.22"W	1128
Tiaret	34°38'50.48"N	1°35'36.51"E	1025
Tiaret	34°47'41.59"N	1°55'17.06"E	1024
Tiaret	35°02'15.12"N	1°57'45.42"E	1074
Tiaret	35°23'0.51"N	1°02'15.40"E	584
Tiaret	35°00'17.56"N	1°55'38.02"E	1263
Tiaret	34°49'45.77"N	0°45'51.57"E	957
Tiaret	35°28'42.87"N	1°22'51.27"E	885
Tiaret	35°16'21.07"N	1°53'12.20"E	914
Tiaret	34°05'51.52"N	1°20'32.89"E	1145
Tiaret	35°06'15.60"N	1°40'03.08"E	1314
Tiaret	34°28'18.59"N	1°37'27.37"E	1064
Tiaret	34°37'46.81"N	2°02'06.43"E	984
Tiaret	34°40'37.24"N	1°06'07.05"E	1040
Tiaret	34°39'46.95"N	1°44'59.89"E	1023
Tiaret	35°07'28.52"N	1°08'18.99"E	1098
Tissemsilt	35°41'50.34"N	1°31'25.45"E	680
Tissemsilt	35°35'23.30"N	1°39'16.98"E	745
Tissemsilt	35°49'27.26"N	1°36'33.79"E	923
Tissemsilt	35°38'01.17"N	1°54'13.08"E	953
Saïda	34°30'22.95"N	0°44'36.02"E	1036
Saïda	34°48'59.59"N	0°18'32.81"E	1102
Sidi Bel Abbès	34°28'02.38"N	0°47'32.20"W	1127
Sidi Bel Abbès	34°11'20.88"N	0°05'54.62"W	1037
Djelfa	35°03'27.51"N	2°46'53.20"E	845
Djelfa	34°32'49.33"N	3°17'16.78"E	1218
Djelfa	35°22'08.91"N	2°33'45.77"E	735
Laghouat	34°08'56.22"N	2°58'58.17"E	1058
Laghouat	33°53'26.45"N	2°12'24.43"E	1286
Laghouat	33°39'19.45"N	2°12'18.14"E	1041
Laghouat	34°14'28.65"N	1°59'21.94"E	1202
El Bayadh	33°17'06.26"N	1°27'38.21"E	1144
El Bayadh	33°52'21.86"N	0°27'53.80"E	1085
El Bayadh	33°00'57.00"N	0°28'58.80"E	1089
El Bayadh	33°41'06.46"N	1°19'17.14"E	1448
M'Sila	35°32'02.29"N	3°44'17.20"E	662
M'Sila	34°54'13.31"N	3°58'14.07"E	838
Naama	33°35'26.10"N	1°29'41.03"W	1091
Naama	32°51'27.47"N	1°16'23.61"W	1370
Naama	33°51'25.15"N	0°08'29.84"W	1051
Naama	34°00'56.04"N	1°25'17.75"W	1190
Naama	33°24'53.22"N	1°00'37.00"W	1108

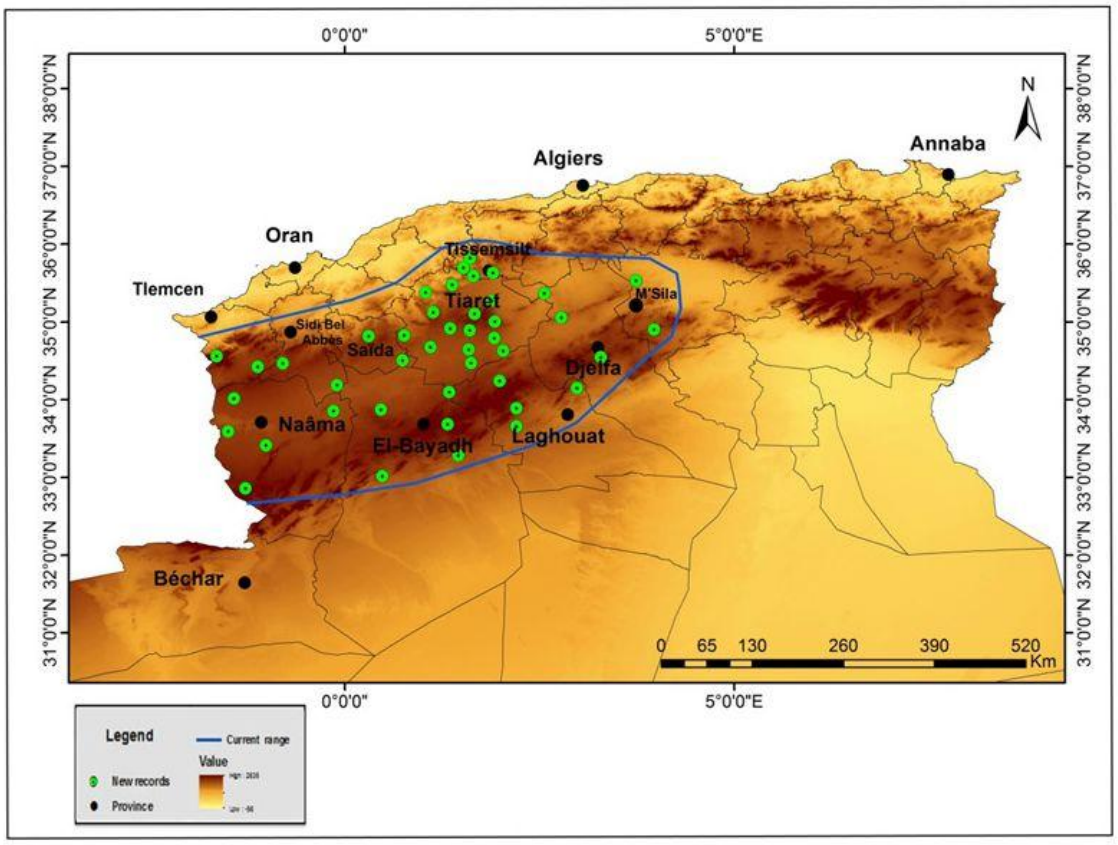

Fig. 6. Map showing the distribution of *Buthus apiatus* in Algeria according to altitude.

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Geographical distribution, potential hybridisation, and comparative morphometric analysis of *Androctonus liouvillei* Pallary, 1924 (Scorpiones: Buthidae) in Algeria

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Abstract

This study updates the geographic distribution and examines the morphometric differentiation of *Androctonus liouvillei*, *A. aeneas*, and their putative hybrids in Algeria. By combining historical records with field surveys conducted between 2021 and 2024, several new localities for *A. liouvillei* in western Algeria were identified. Morphometric analyses of 12 adult females using Principal Component Analysis (PCA), Hierarchical Cluster Analysis (HCA), and Linear Discriminant Analysis (LDA), revealed key morphological differences and as well as intermediate forms. The results indicate that *A. liouvillei* has a restricted, and fragmented distribution, primarily associated with mid-altitude steppe habitats, whereas *A. aeneas* occupies a broader ecological range. Putative hybrids were recorded in sympatric zones, particularly in El Bayadh, Naâma, Béchar, and Tiaret, providing new insights into their biogeography and ecological differentiation.

Keywords: *Androctonus liouvillei*, *Androctonus aeneas*, Scorpions, Hybridization, Sympatric zones, Algeria.

Introduction

Genus *Androctonus* was first described by Hemprich and Ehrenberg 1828 (Braunwalder & Fet, 1998). Since then, the genus has undergone a continuous increase in the number of recognized species. The number rose from 8 species and 14 subspecies in 2000 (Fet & Lowe, 2000; Lourenço, 2005) to 33 species, as reported by Eric Ythier and Wilson R. Lourenço in 2022 (Ythier & Lourenço, 2022). In 2023, the total increased to 36 species following the description of three new taxa (Yağmur, 2023; Al Qahtani *et al.*, 2023; Lourenço, 2023).

By 2026, the number of valid species reached 56 (Rein, 2026), after the description of several new taxa from North Africa and the Middle East, including *A. tinzaouatinensis* Yagmur, Benali, Derradj & Bikada 2026, *A. ammoneus* (Yağmur *et al.*, 2025), *A. ajjer* Ythier, Sadine, Alioua & Lourenço, 2025 (Ythier *et al.*, 2025), *A. najdensis* (Yağmur *et al.*, 2025), *A. omanensis* (Lowe, 2025), three Moroccan species described by Kovařík *et al.* (2025), a new Jordanian species (Abu Afifeh *et al.*, 2025), *A. nazarii* (Salabi *et al.*, 2025), and *A. ishtar* (Yağmur *et al.*, 2025). This steady growth reflects ongoing discoveries and an improved understanding of the genus diversity, although the taxonomic status of several species remains uncertain.

In Algeria, *Androctonus* is currently represented by eight species. Recently, a new species from In Guezzam and Bordj Badji Mokhtar in the extreme southern part of Algeria, *A. tinzaouatinensis*, was described by Yağmur *et al.* (2026). This species is considered the fourth endemic one, after *A. eburneus* (Pallary, 1928), *A. hoggarensis* (Pallary, 1929), and *A. ajjer* (Ythier *et al.*, 2025). Moreover, the distribution of *A. aeneas* C.L. Koch, 1839 has been reassessed, revealing a significant westward and south-westward expansion of its range in Algeria, including Aïn Témouchent, Sabdou, El Bayadh, Saïda, Naâma, and Béchar (Ait Hammou *et al.*, 2024). The Algerian fauna also includes *A. liouvillei* (Pallary, 1924), with each species characterized by specific bioecological affinities and a variable distribution across the country.

According to Vachon (1952), *A. liouvillei* occurs in northwestern Algeria, specifically in Beni Ounif (Béchar), Géryville (currently El Bayadh and Arbaouat), Aïn Sefra, and Sidi Bel Abbès. Vachon (1952) reported that *A. liouvillei*, an Algerian–Moroccan endemic species, was originally described by Paul Pallary in 1924 from Moroccan specimens under the name *Buthus (Prionurus) liouvillei* (GBIF, 2025).

This species has generated considerable debate regarding its specific validity. Several authors have suggested that it might be synonymous with other species such as *A. mauretanicus*, *A. bicolor*, or *A. crassicauda*, mainly due to the insufficient original description and the limited knowledge of the genus *Androctonus* at that time.

This study focuses on the geographic distribution and habitats of *A. liouvillei* in Algeria. The main objective is to update the spatial distribution of *A. liouvillei* by providing new records, particularly from the western regions of the country. These data complement previous observations of the species in Algeria, and an updated national distribution map is presented.

In parallel with this biogeographical update, we examined the morphological differentiation between *A. liouvillei* and the closely related species *A. aeneas*, with which it partially coexists in certain regions. The sympatric occurrence of these two scorpions suggests the possibility of natural hybridization events.

To explore this hypothesis, a morphometric analysis was conducted on female specimens of *A. liouvillei*, *A. aeneas*, and presumed hybrid individuals collected from contact zones between the two species. This approach aims to characterize size and shape

variation within and between these groups and to identify discriminant morphological criteria that may allow potential hybrids to be distinguished from their parental specie.

By combining the updated geographic distribution of *A. liouvillei* with this detailed morphometric analysis, our study provides a comprehensive overview of the diversity and differentiation of this species in Algeria, addressing both its spatial range and its morphological relationships with closely related species.

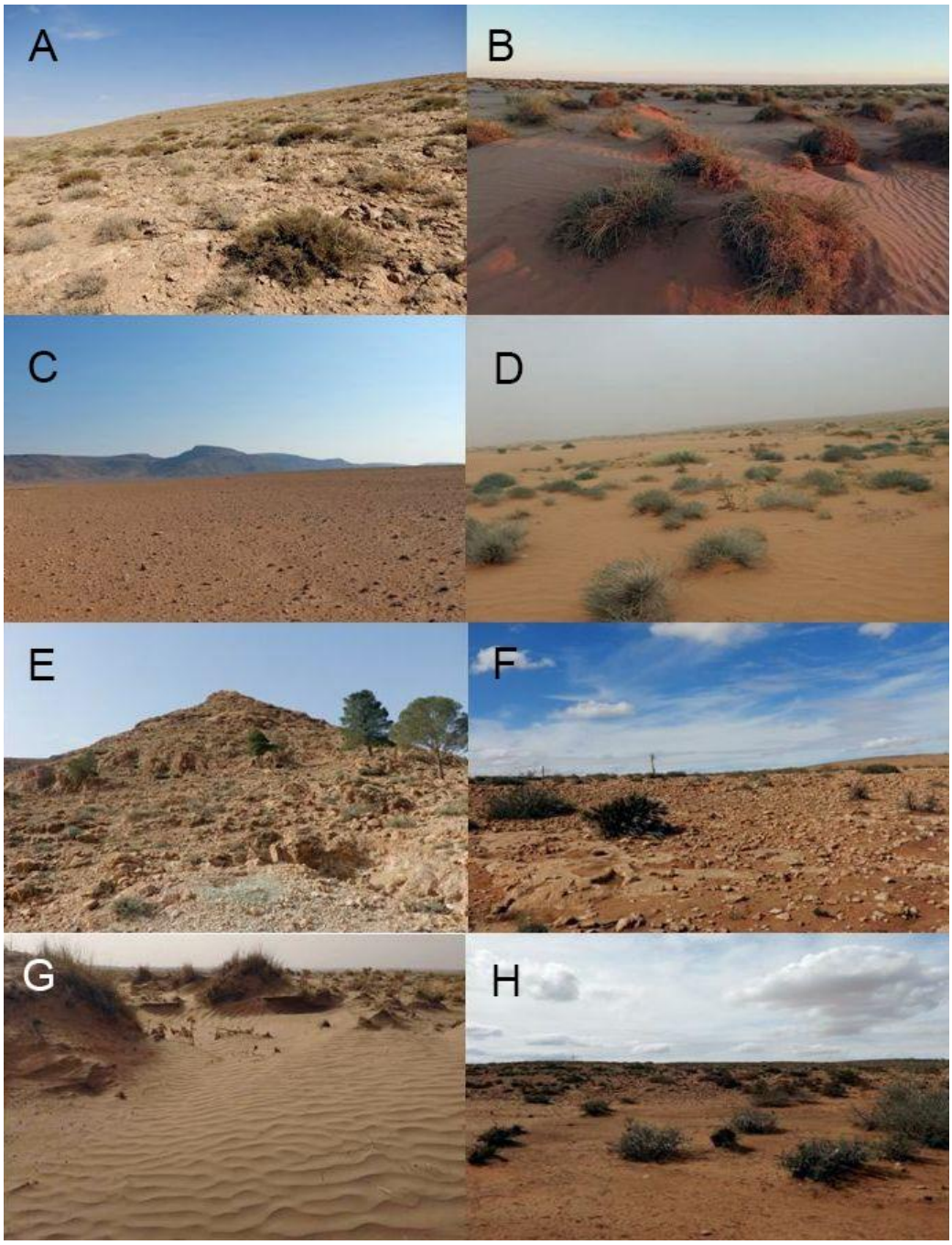

Fig. 1. Different biotopes inhabited by *Androctonus liouvillei* (Pallary, 1924). A. Uncultivated plains. B. Stony plain. C. Ploughed abandoned steppe soil. D. *Lygeum spartum* grass stand. E. Alfa grass (*Stipa tenacissima*) stand. F. Wormwood (*Artemisia*) stand. G. Abandoned almond orchard. H. Over grazed alfa grass stand Nappe and alfa over grazed.

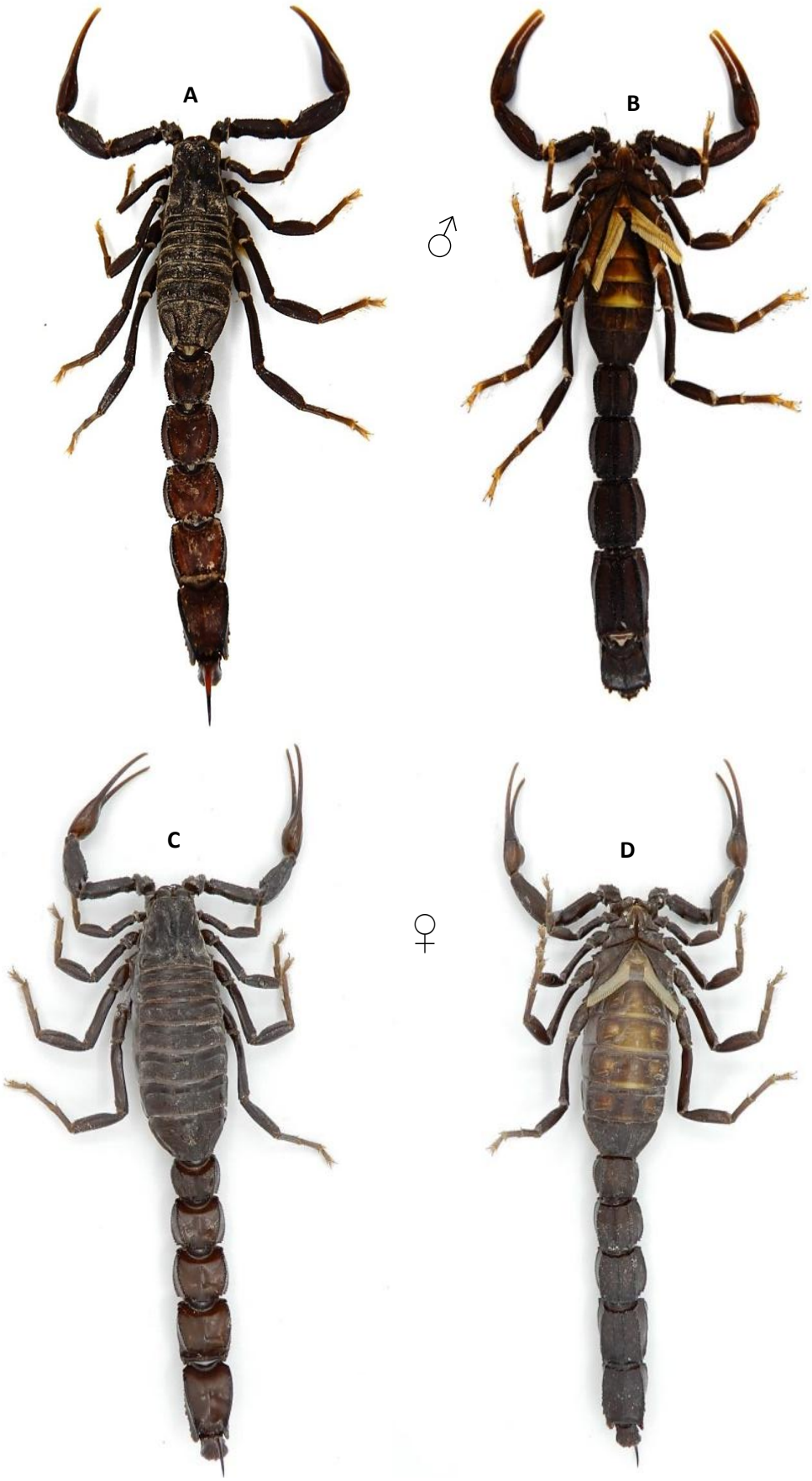

Fig. 2. *Androctonus liouvillei* (Pallary 1924). A-B. Male. C-D. Female. A, C. dorsal view. B, D. ventral view.

Material and Methods

Scorpion Sampling

This study on the distribution of *Androctonus liouvillei* in Algeria is based on both historical data, particularly those reported by Max Vachon (1952), and recent field observations.

Between January 2021 and September 2024, we began by visiting several historical localities in order to collect specimens and to compare them with earlier descriptions, which allowed us to refine our understanding of their morphology. We subsequently conducted scorpion surveys across various biotopes (Fig. 1) throughout the country, including steppes, uncultivated plains, sandy formations, and areas dominated by Alfa (*Stipa tenacissima*), *Artemisia*, and *Atriplex* vegetation.

In parallel, interviews were carried out with local inhabitants and health services to gather additional information on the species' distribution. These exchanges facilitated the identification of new localities where *A. liouvillei* is present, thereby improving our knowledge of its distribution in Algeria and contributing to the update of its distribution map. Overall, this study enhances our understanding of national biodiversity and supports efforts aimed at the management and conservation of scorpion species.

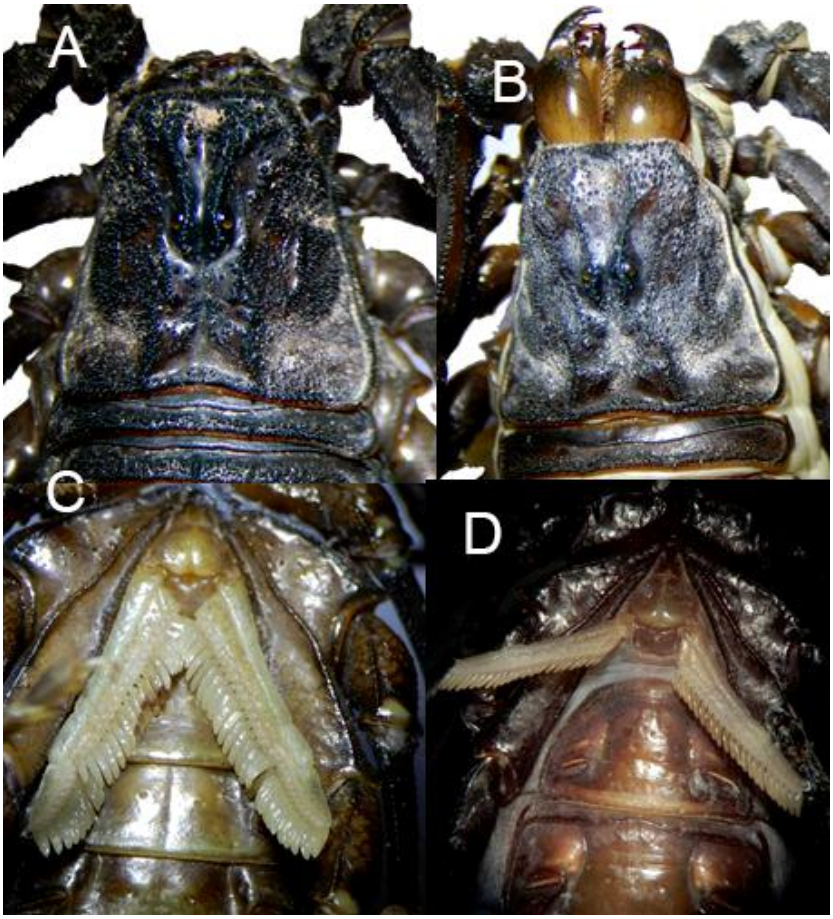

Fig. 3. *Androctonus liouvillei* carapace and sternopectinal area. A, C. Male. B, D. Female. A-B. carapace. C-D. sternopectinal area.

Scorpion Identification

The specimens were killed and kept in 96% alcohol (ethanol). Identification was obtained using a stereo-microscope to highlight the distinctive and specific characteristics of the species (Fig. 2) according to the criteria established by Vachon (1952).

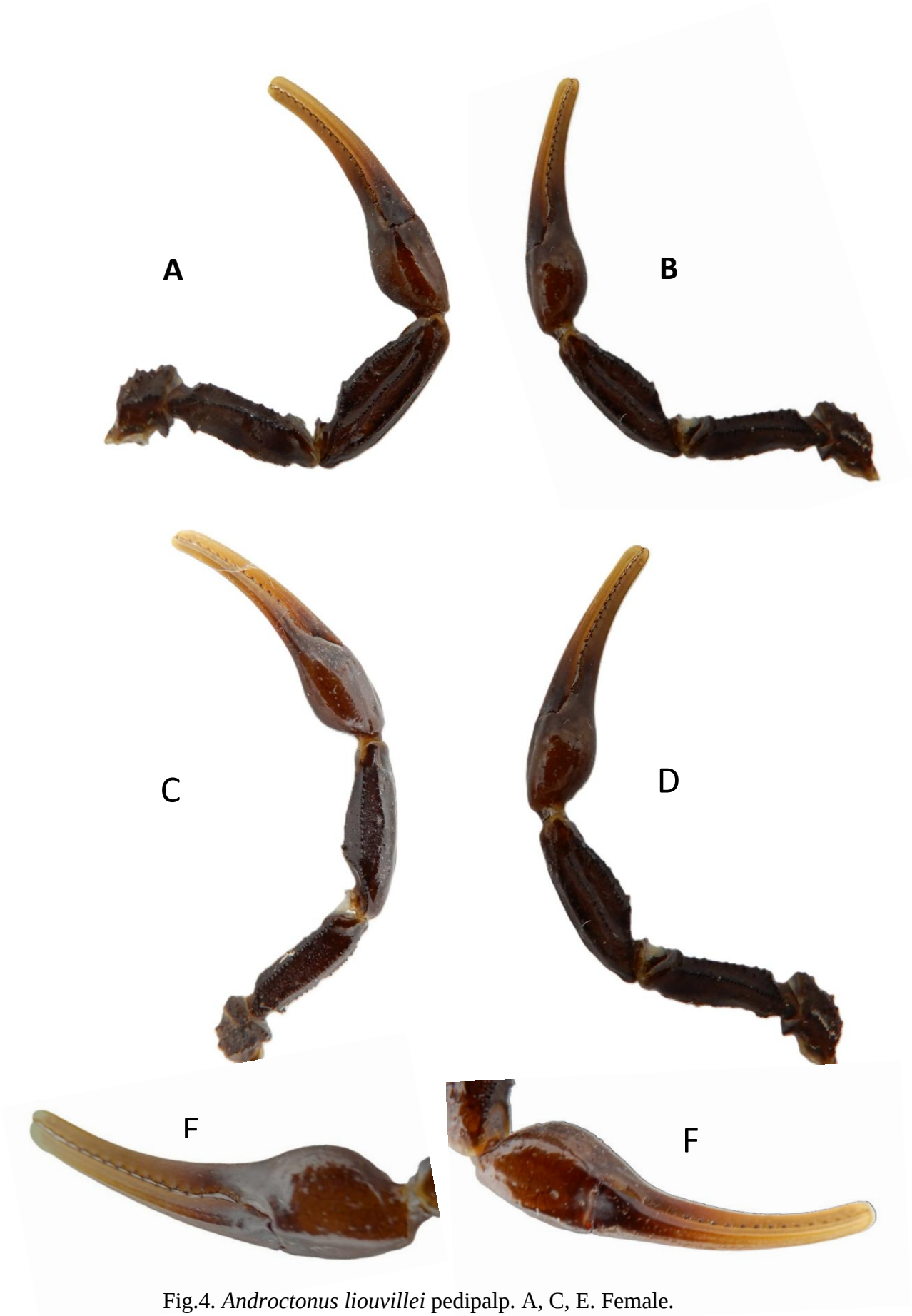

Fig.4. *Androctonus liouvillei* pedipalp. A, C, E. Female.
B, D, F. Male. A,C. dorsal view. B, D. ventral view. E-F. Chela.

Fig. 5. *Androctonus liouvillei* metasoma and telson. A, C, E. Female. B, D, F. Male. A-B. lateral view. C-D. dorsal view. E-F. ventral view.

Results
Systematic Position

Family **Buthidae** C.L. Koch, 1837
Genus ***Androctnus*** Ehrenberg, 1828
Androctonus liouvillei (Pallary, 1924) (Figs. 2-7)

Material of *Androctonus Liouvillei* from Algeria cited by Vachon (1952):

Androctonus Aeneas C.L.K. *Liouvillei* (Pallary), var. — ALGERIE, **dép. d'Oran**, coll. LS, Dr FOLEY, 1913, 3♂, 1 ♀ ; Dr BROUARD, 1923, 2 ♀, 3 ♂. **Beni Ounif (Bechar)**, coll. LS n° 401, D[r] HORRENBERGER, avril 1932, 2 ♀, 1 ♂ : dét. Pr. Liouvillei par M. le Docteur FOLEY ; n° 700, D[r] MONTFORT, déc. 1934, 2 ♀, 2 ♂, n° 1074, D[r] FOLEY, dans une chambre d'hôtel, 1 ♀ ; n° 1124, D' FOLEY, déc. 1938, 1 ♀, 2 ♂, dét. Pr. Liouvillei par M. le D[r] FOLEY ; n° 1591, Dr FOLEY, avr. 1941, dans l'hôtel, 1 ♀ , dét. Pr. Liouvillei par M. le Dr FOLEY ; n° 2278, D' FOLEY, 24 oct. 1941, dans l'hôtel, 1 ♂ ; n° 4620, D[r] BURAND-DELACRE, dans maison, oct. 1945, 1 ♀ im. ; Dr FOLEY, envoi n° VIII, avr. 1946, 1 ♀, 1 ♂. **Géryville (bayadh)**, coll. LS, n° 260; Dr BREYFUSS, 18 juin 1929, 1 ♀ ad., 1 ♂, 1 ♂ im. ; n° 282, id., nov. 1930. 3 ♀, 1 ♂ ; n° 264, id., juil. 1929, 1 ♀, 3 ♂ .**Ain Sefra**, coll. LS, n° 442, E. GAGET, 5 ♀, 1 ♂. **Arbaouat**, 80 km. Sud de **Géryville (bayadh)**, D' RoussEL, 1 ♂ , 1 ♀. **Sidi Bel Abbés**, coll. Em. BONNET leg., 4 ♀, 2 ♂.

Fig. 6. *Androctonus liouvillei* left legs I-IV.

Description

Medium-sized scorpions. Average body length 92.60 mm and 117.16 mm. General colouration of the scorpion ranges from dark brown to blackish brown. Carapace carinae strong and bear coarse granules in males, and moderate granules in females. Intercarinal areas densely covered with coarse to medium granules in males. Chela manus smooth and lustrous; internal surface densely granular in males.

Movable fingers of the pedipalps bear 16 rows of denticles, with external and internal accessory denticles and three distal granules. Fixed fingers bear 15 rows of granules, also with external and internal accessory granules and three distal granules. Pectines bear 26–26 teeth in males and 20–20 in females.

Colouration

Base colouration dark brown to blackish brown. Carapace and tergites dark brown with darker granules. Pedipalps dark brown. Chela manus darker externally and slightly lighter ventrally. Legs yellowish to brown. Metasoma brown to dark brown. Telson vesicle brown to dark brown; aculeus darker distally.

Morphology

Prosoma

Carapace moderately to strongly granulated, particularly on the anterior region. Furrows distinct. Ocular tubercle situated slightly anterior to the centre of the carapace.

Mesosoma

Tergites moderately granulated. Sternites mostly smooth, with fine granulation on posterior segments.

Metasoma

Segments moderately robust. Segment I dorsally strongly granulated. Granulation decreases on segment II and is often absent on segment III. Lateral surfaces weakly granulated on anterior segments and slightly more developed on posterior segments, though anterior and posterior areas remain smooth. Ventral surfaces smooth, with fine granulation on the last two segments.

Telson

Vesicle narrow, approximately half as wide as metasomal segment V in some individuals and distinctly wider in others. Aculeus moderately curved.

Pedipalps

Forearm (patella) distinctly thicker than the femur and about three times wider than long. Internal surface bears a few accessory macrosetae. Chela manus thick, slightly longer than wide and wider than the patella. External surface smooth with weak indications of carinae; internal surface granulated. Fingers slightly curved, about twice as long as the manus. Fixed finger with a slight basal notch; movable finger with a slight dilation not completely filling the notch. Each finger with 13–16 rows of denticles.

Chelicerae

Dorsal surface of cheliceral manus bearing a posterior internal macroseta and a median seta.

Legs

Walking legs with basitarsal spur bearing a simple or bifid basal tooth, condition variable among specimens. Spur with numerous setae. Claws slender.

Fig. 7. A-B. *Androctonus liouvillei*. C. *Hybrid* (*A. liouvillei* X *A. aeneas*) from Algeria.

Recent material

The material cited in recent publications, also the new observation points, are summarized in Table (1).

Table 1. New observation points of *Androctonus liouvillei* in Algeria.

Province	Region	Latitude	Longitude	Altitude (m)	Type	References
Tlemcen	El Aricha	34°19'10.576"N	1°13'28.483"W	1068	Ploughed and abandoned steppe soil	El Bouhissi M. 2024
Tlemcen	Sebdou	34°31'39.2"N	1°21'12.7"W	1139	Ploughed and abandoned steppe soil	El Bouhissi M. 2024
Ain Temouchent	Sassel	35°12'36.0"N	1°32'24.0"W	366	Degraded maquis	GBIF 2008
Bechar	Djeniene Bourezg	32°22'59.3"N	0°47'42.9"W	1023	Orchard	El Bouhissi M. 2022
Bechar	Oued enamous	31°41'12.5"N	0°25'28.7"W	715	Steppe zone	El Bouhissi M. 2023
Naâma	Naâma	33°15'49.10"N	0°18'18.50"W	1173	Green belt of Aleppo pine	El Bouhissi M. 2023
Sidi belabes	Guetarnia	35°17'39.8"N	0°13'31.2"W	717	Maquis	El Bouhissi M. 2024
Sidi belabes	Bir el hmmam	34°25'09.6"N	0°30'24.7"W	1177	Rocky sandy terrain with stones	El Bouhissi 2024
Sidi belabes	Rdjemd emouche	34°27'10.4"N	0°54'07.1"W	1130	Degraded steppe zone	El Bouhissi M. 2024
Mascara	Bouhnifia	35°15'59.6"N	0°12'36.5"W	618	Maquis	El Bouhissi M. 2024
Djelfa	Hassifedhoul	34°37'10.1"N	3°12'45.1"E	1202	Uncultivated soil	Ait Hammou 2023
Laghouat	Gueltat Sidi Saad,	34°15'13.7"N	1°48'33.5"E	1207	Degraded steppe	Ait Hammou 2023
Bayadh	Arbaouet	33°05'24.3"N	0°35'06.1"E	1039	Degraded steppe	Belakhdar T. 2024
Bayadh	Arbaouet	33°05'24.3"N	0°35'06.1"E	1033	Village of Arbaouet	Belafdhal B. 2024
Saïda	Aïn El Hadjar	34°49'59.6"N	0°09'24.8"W	833	Agricultural area	Ait Hammou M. 2023
Tiaret	Sidi Abd errahmane	34°34'28.1"N	0°50'40.8"E	1028	Ploughed and abandoned steppe soil	Ait Hammou M. 2023
Tiaret	Sidi Abd errahmane	34°37'43.9"N	0°55'41.0"E	1002	Ploughed and abandoned steppe soil	Ait Hammou M. 2023

Tiaret	Sidi Abd errahmane	34°45'22.4"N	1°04'22.4"E	1091	Ploughed and abandoned steppe soil	Ait Hammou M. 2023
Tiaret	Sidi Abd errahmane	34°46'41.22"N	1°06'34.44"E	1067	Ploughed and abandoned steppe soil	Ait Hammou M. 2023
Tiaret	Madna	34°42'42.4"N	0°59'27.2"E	1028	Agricultural plains	Ait Hammou M. 2023
Tiaret	El-Faidja	34°57'42.55"N	1°48'5.71"E	1276	Wormwood (*Artemisia*) stand	Dahmani W. 2023
Tiaret	El-Faidja	35°01'19.2"N	1° 48' 40.8"E	1326	Wormwood (*Artemisia*) stand	Dahmani W. 2023
Tiaret	El-Faidja	35°01'26.7"N	1°49'02.2"E	1359	Wormwood (*Artemisia*) stand	Ait Hammou M. 2023
Tiaret	Ksar Chellala	35°17'24.66"N	2°18'44.07"E	762	Agricultural area	Ait Hammou M. 2023
Tiaret	Taguine	34°57'57.54"N	2°22'28.39"E	802	Natural rangeland	Ait Hammou M. 2023
Tiaret	Faidja	35°06'18.01"N	1°42'05.82"E	1233	Agricultural area	Ait Hammou M. 2023
Tiaret	Naima	34°36'40.88"N	1°50'47.46"E	1020	Stony plains	Ait Hammou M. 2023
Tiaret	Ain Deheb	34°55'03.53"N	1°31'30.34"E	1156	Overgrazed alfa grass stand	Ai tHammou M. 2023
Tiaret	Ain Deheb	34°55'01.7"N	1°31'15.2"E	1141	Uncultivated plains	Ait HammouM. 2023
Tiaret	Naima	34°34'23.0"N	1°45'06.9"E	1026	Stony plain	Ait Hammou M. 2023
Tiaret	Chehaima	34°26'12.6"N	1°13'58.00"E	1028	Uncultivated plains	Ait Hammou M. 2023
Tiaret	Chehaima	34°23'55.80"N	1°13'41.50"E	1036	Uncultivated plains	Ait Hammou M. 2023
Tissemsilt	Layoune	35°39'28.6"N	2°00'53.6"E	864.33	Stony plain	Cheddad A. 2024
Tissemsilt	Layoune	35°37'58.5"N	2°01'58.4"E	827.7	Ploughed and abandoned steppe soil	Cheddad A. 2024
Tissemsilt	Selmana	35°35'42.70"N	2° 5'37.90"E	831.2	Uncultivated plains	Benali N. 2024
Tissemsilt	Selmana	35°41'22.0"N	2°00'33.9"E	900.6	Uncultivated plains	Dahmani W. 2024
Tissemsilt	Selmana	35°34'31.1"N	2°08'30.2"E	872	Abandoned almond orchard	Benali N. 2024

Genus *Androctonus* illustrates the biogeographic complexity of the Maghreb, where arid and semi-arid zones act as ecological corridors for numerous species (Fet & Lowe, 2000; Lourenço, 2005). In this context, *A. aeneas* and *A. liouvillei* represent two contrasting models in terms of distribution and ecology.

A. aeneas, a generalist and widely distributed species, occupies an almost continuous belt extending from eastern Algeria (Tébessa, Batna, Khenchela) to the west and southwest (Naâma, Béchar, Tiaret, Oran). This horizontal expansion, previously noted by Lourenço *et al.* (2015) and Sadine (2018), is confirmed and further enriched by our surveys, which reveal new western and northwestern localities (Tiaret, Sétif, Sidi Bel Abbès, Saïda, El Bayadh). The species thus spans several bioclimatic zones, from the subhumid areas of the High Plateaus to the Saharan margins, reflecting remarkable ecological tolerance. With an altitudinal range from 25 to 1633 m (Aït Hammou *et al.*, 2024), it exploits a wide variety of biotopes, including anthropized environments (farms, abandoned fields) as well as extreme habitats such as Saharan regs and palm groves (Sadine, 2018).

Table 2. Morphometric Analysis and Group Discrimination: *Androctonus liouvillei*, *Androctonus aeneas*, and Hybrid forms.

Dimensions (mm)	*A. liouvellei* Tiaret Ain Deheb ♀	*A. liouvellei* Arbouat bayadh ♀	*A. liouvellei* Tiaret Ain Deheb ♀	*A. liouvellei* Arbouat bayadh ♀	*A. liouvellei* Guetaifa ♀	*A. liouvellei* Mahdia ♀	*A. liouvellei* Tiaret Ain Deheb ♀	Hybrid Faidja ♀	Hybrid Saida ♀	Hybrid Sidi Belabes ♀	*Androctonus aeneas* Rechaiga ♀	*Androctonus aeneas* Ain Deheb ♀
Total Length	108.51	124.71	117.16	103.98	93.00	92.60	94.27	87.37	96.29	86.55	69.23	102.17
Carapace Length	32.46	40.44	38.50	31.27	27.56	29.27	28.20	27.35	30.91	26.92	6.97	29.44
Carapace anterior width	7.59	7.28	6.87	6.44	7.48	6.20	6.65	5.93	5.92	5.73	3.94	6.79
Carapace posterior width	10.66	11.32	10.56	11.00	10.11	9.30	9.69	8.58	8.77	7.75	7.39	9.77
Mesosoma length	29.00	29.54	29.40	21.00	18.60	19.70	23.10	18.65	23.01	18.57	22.02	24.80
Metasomal segment I length	6.07	7.30	6.03	6.80	5.35	5.54	6.04	5.14	5.40	5.41	5.52	6.54
Metasomal segment I width	7.09	7.60	7.17	7.00	7.03	6.14	5.92	6.48	6.20	6.23	5.37	6.15
Metasomal segment II length	7.04	8.46	7.09	7.40	7.70	6.89	6.29	6.26	6.02	6.00	6.04	6.90
Metasomal segment II width	7.60	7.84	7.55	7.82	7.19	7.35	7.09	6.86	6.60	6.50	5.85	7.15
Metasomal segment III length	7.45	8.70	7.45	8.15	7.61	6.70	6.39	6.06	7.07	6.33	6.27	7.33
Metasomal segment III width	7.72	8.70	8.13	8.01	8.01	7.62	7.52	7.70	7.67	6.75	6.02	7.80
Metasomal segment IV length	8.64	9.19	9.09	9.74	8.49	7.72	7.84	7.75	7.64	7.86	7.46	8.34
Metasomal segment IV width	8.10	8.29	7.92	7.80	7.66	7.02	7.30	7.37	6.64	6.92	5.76	7.60
Metasomal segment V length	9.39	10.74	10.25	11.17	9.39	8.58	8.30	8.94	9.09	8.27	7.79	9.55
Metasomal segment V Width	6.75	7.23	7.12	7.44	6.70	6.20	6.53	6.40	5.84	6.33	5.17	7.58
Telson Length	8.46	10.34	9.35	8.45	8.30	8.20	8.11	7.22	7.15	7.19	7.16	9.27
Telson Width	4.01	9.58	4.42	4.93	4.94	3.95	3.32	3.65	3.50	3.42	2.57	3.67
Femur Length	6.79	9.12	8.74	8.80	9.60	7.52	6.56	7.51	7.29	6.95	6.09	6.60
Femur Width	1.80	2.60	2.13	2.54	2.20	2.14	1.91	2.04	2.07	1.95	1.99	1.95
Patella Length	9.15	11.01	10.00	10.89	9.52	8.45	8.91	9.43	9.36	8.21	6.89	9.42
Patella Width	2.80	2.66	3.32	3.45	3.20	2.42	2.49	3.15	3.13	3.10	2.34	2.62
Chela Length	16.35	18.27	16.55	17.31	15.71	13.71	14.25	14.63	14.50	13.33	11.20	15.46
Chela Width	3.28	4.15	3.75	3.69	3.38	2.40	2.44	3.33	3.21	3.04	1.94	2.62
Movable finger Length	9.45	13.12	11.42	12.18	11.03	9.42	9.60	10.24	10.25	9.59	7.43	10.13

In contrast, *A. liouvillei*, originally described by Pallary (1924) and later reassessed by Vachon (1952), exhibits a more restricted and discontinuous distribution, mainly confined to western Algeria and Morocco (El Hidan *et al.*, 2017; Es-Saadi *et al.*, 2025). Our field surveys confirm this fragmented pattern, recording the species in several focal areas: Tlemcen (El Aricha, Sebdou), Aïn Témouchent (Sassel), El Bayadh, Naâma, Béchar (Djénene Bourezg, Oued Enamous), Sidi Bel Abbès, and Laghouat. Its altitudinal range, between 366 and 1359 m, with a median around 1028 m (Table 1), indicates a marked affinity for mid-altitude steppe environments. The species primarily inhabits alfa grass (*Macrochloa* (*Stipa*) *tenacissima*) and wormwood (*Artemisia*) steppes, as well as stony or sandy soils, abandoned fields, and degraded maquis (Es-Saadi *et al.*, 2025). Although some observations confirm its presence in anthropized settings (orchards, abandoned cultivated areas) (Fig. 1), its ecological plasticity remains clearly more limited than that of *A. aeneas*.

Comparison of the two distribution maps highlights areas of overlap, particularly in El Bayadh, Naâma, Béchar, and Tiaret, where both species coexist in semi-arid steppe habitats. These zones of sympatry suggest regular interspecific contact and raise the hypothesis of potential ecological or genetic interactions. From a biogeographic perspective, these areas appear to function as transitional zones between Moroccan and Algerian populations of *A. liouvillei*, and between eastern and western populations of *A. aeneas*.

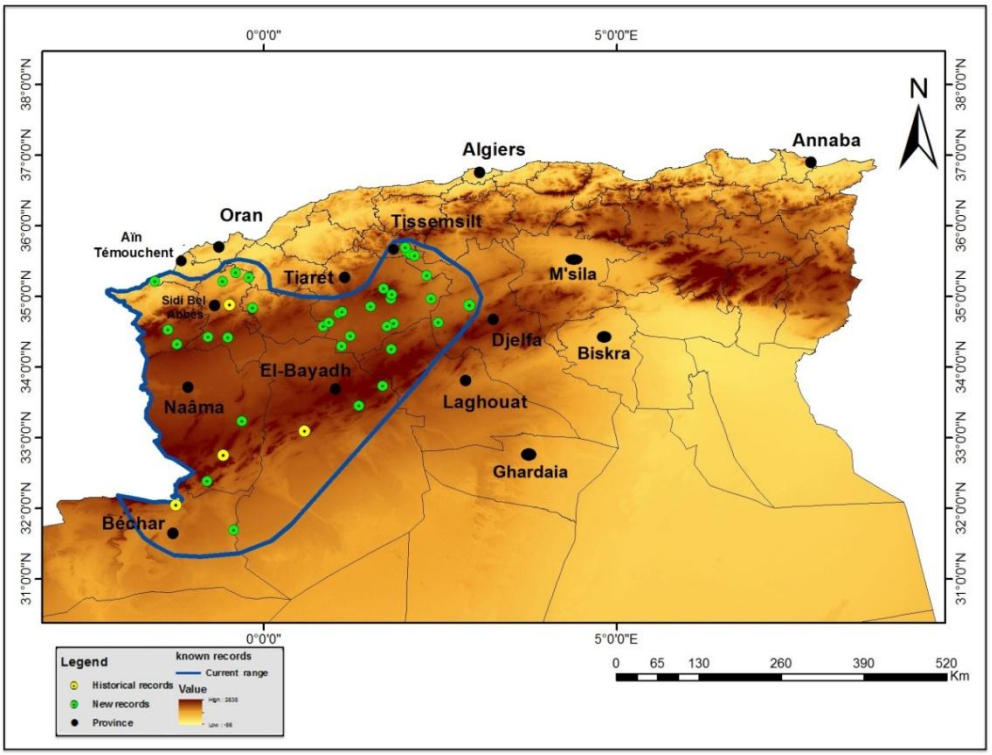

Fig. 8. Map showing the confirmed distribution of *Androctonus liouvillei* in Algeria according to altitude.

Our data also reveal additional areas of co-occurrence, notably in Tissemsilt, Aïn Témouchent, Sidi Bel Abbès, Djelfa, and Laghouat (Ait Hammou *et al.*, 2024). Among these, Tiaret stands out as a major sympatric hotspot, where both species are frequently encountered in similar habitats (stony plains, degraded steppe soils, alfa, and wormwood stands, abandoned fields). These overlap zones, mostly located around 1000 m elevation,

provide favourable conditions for close ecological contact and raise the question of possible hybridization phenomena, especially since recent morphometric analyses suggest the presence of intermediate forms.

Finally, the newly documented localities for *A. aeneas* (Tiaret, Sétif, Sidi Bel Abbès, El Bayadh, Saïda) indicate an extension toward western and northwestern Algeria, thereby updating the east-west distribution belt proposed by Lourenço *et al.* (2015) and Sadine (2018). This extension confirms the species ability to colonize new territories and provides valuable insights into the dynamics of its spatial expansion. Meanwhile, records of *A. liouvillei* further clarify its stronghold in western and southwestern Algeria (El Hidan *et al.*, 2018; Es-Saadi *et al.*, 2025), while emphasizing its zones of overlap with *A. aeneas* in transitional steppe environments.

In summary, the combined evidence from the literature and recent field surveys highlights two distinct strategies: *A. aeneas*, a generalist species with broad distribution and strong ecological plasticity, and *A. liouvillei*, a more specialized and localized species. The sympatric zones identified in western Algeria are crucial for understanding the evolutionary dynamics of these taxa, their potential interactions, and the public health implications associated with their venom (Lourenço *et al.*, 2015; Sadine, 2018; Es-Saadi *et al.*, 2025; Ait Hammou *et al.*, 2023).

Morphometric Analysis

A morphometric study was conducted on females from three groups of *Androctonus* scorpions: *A. liouvillei*, *A.aeneas*, and putative hybrid individuals collected from contact zones between these two species. These species exhibit partial sympatry, suggesting the possibility of natural hybridization events. The morphometric analysis aimed to characterize shape and size variation within and between these groups to improve understanding of their differentiation.

The specific objectives of this study were to:

- **Compare** the morphometric characteristics of females of *Androctonus liouvillei*, *Androctonus aeneas*, and the hybrid forms;
- **Identify** discriminant morphological traits that allow hybrid individuals to be distinguished from their parental species;
- **Determine** the relative morphological position of the hybrids within multivariate space in relation to the two parental species.

In this section, we present the procedures used for sampling and morphometric analysis of the studied specimens.

A total of 12 adult female specimens were analyzed, including 7 *Androctonus liouvillei*, 2 *Androctonus aeneas*, and 3 hybrids (presumed offspring of a ♂ *A. aeneas* × ♀ *A. liouvillei* cross).

For each specimen, a set of 23 morphometric variables was measured in millimetres, covering key body and appendage dimensions:

- Carapace (cephalothorax) length
- Anterior and posterior carapace widths
- Mesosoma length
- Lengths and widths of metasomal segments I-V (postabdomen)
- Telson (sting) length and width
- Pedipalp femur and patella length and width
- Chela (pincer) length and width
- Movable finger length

These measurements provide a comprehensive characterization of the size and shape of each individual.

Statistical Analyses

The morphometric data were normalized (converted to z-scores) to remove the effect of scale differences among variables prior to multivariate analyses.

A Principal Component Analysis (PCA) was first performed to explore the overall variation among individuals and to visualize potential natural groupings without any *a priori* assumptions. Subsequently, a hierarchical cluster analysis (HCA) using Ward's method based on Euclidean distances was conducted to identify morphometric groupings of individuals into distinct clusters.

In addition, inter-group comparisons were conducted for each variable. Given the small sample size and the potential non-normality of some distributions, a non-parametric Kruskal-Wallis test (a one-way ANOVA equivalent) was used to identify variables showing significant differences among *A. liouvillei*, *A. aeneas*, and the hybrids.

For comparison, a classical one-way ANOVA was also performed on each variable when appropriate, followed by a Tukey HSD (Honestly Significant Difference) post-hoc test to determine which pairs of groups differed significantly.

Finally, a Linear Discriminant Analysis (LDA) was conducted to maximize group separation based on the measured variables and to identify the linear combination of morphometric traits that best discriminates among *A. liouvillei*, *A. aeneas*, and the hybrids.

Table 3. Means ± standard deviations of morphometric variables by group. Values are given in millimetres. (*A. liouvillei* : *Androctonus liouvillei*; Hybrids : hybrid individuals; *A. aeneas* : *Androctonus aeneas*.)

Variable	*A. liouvellei* (moy. ± σ)	Hybrids (moy. ± σ)	*A. aeneas* (moy. ± σ)
Carapace length	32.53 ± 4.69	28.39 ± 1.79	18.21 ± 11.24
Carapace anterior width	6.93 ± 0.50	5.86 ± 0.09	5.37 ± 1.43
Carapace posterior width	10.38 ± 0.72	8.37 ± 0.54	8.58 ± 1.68
Mesosoma length	24.33 ± 4.86	20.08 ± 2.54	23.41 ± 1.97
Metasomal segment I length	6.16 ± 0.68	5.32 ± 0.15	6.03 ± 0.72
Metasomal segment I width	6.85 ± 0.60	6.30 ± 0.15	5.76 ± 0.55
Metasomal segment II length	7.27 ± 0.68	6.09 ± 0.14	6.47 ± 0.61
Metasomal segment II width	7.49 ± 0.29	6.65 ± 0.19	6.50 ± 0.92
Metasomal segment III length	7.49 ± 0.79	6.49 ± 0.52	6.80 ± 0.75
Metasomal segment III width	7.96 ± 0.40	7.37 ± 0.54	6.91 ± 1.26
Metasomal segment IV length	8.67 ± 0.73	7.75 ± 0.11	7.90 ± 0.62
Metasomal segment IV width	7.73 ± 0.44	6.98 ± 0.37	6.68 ± 1.30
Metasomal segment V length	9.69 ± 1.08	8.77 ± 0.44	8.67 ± 1.24
Metasomal segment V width	6.85 ± 0.43	6.19 ± 0.31	6.38 ± 1.70
Telson length	8.74 ± 0.81	7.19 ± 0.04	8.22 ± 1.49
Telson width	5.02 ± 2.09	3.52 ± 0.12	3.12 ± 0.78
Femur length	8.16 ± 1.20	7.25 ± 0.28	6.35 ± 0.36
Femur width	2.19 ± 0.30	2.02 ± 0.06	1.97 ± 0.03
Patella length	9.70 ± 0.98	9.00 ± 0.69	8.16 ± 1.79
Patella width	2.91 ± 0.42	3.13 ± 0.03	2.48 ± 0.20
Chela length	16.02 ± 1.62	14.15 ± 0.72	13.33 ± 3.01
Chela width	3.30 ± 0.66	3.19 ± 0.15	2.28 ± 0.48
Movable finger length	10.89 ± 1.46	10.03 ± 0.38	8.78 ± 1.91

Results of Morphometric Variables

Before examining the comparative analyses, the table above provides a statistical summary of all measured variables, presented as group means ± standard deviation (Table 3). This table allows visualization of general trends, particularly size differences among groups for each morphometric character. For example, *A. liouvillei* tends to exhibit slightly larger body dimensions on average than *A. aeneas* (e.g. carapace length, segment widths), whereas the hybrids display intermediate values for many parameters.

※ Note: The data for the variable *Movable Finger Length* (length of the movable finger of the pedipalp) appear to show a higher mean value in hybrids and *A. aeneas* compared to *A. liouvillei*. This trend may be influenced by the very small sample size of *A. aeneas* and considerable individual variability, and should therefore be interpreted with caution.

Principal Component Analysis (PCA)

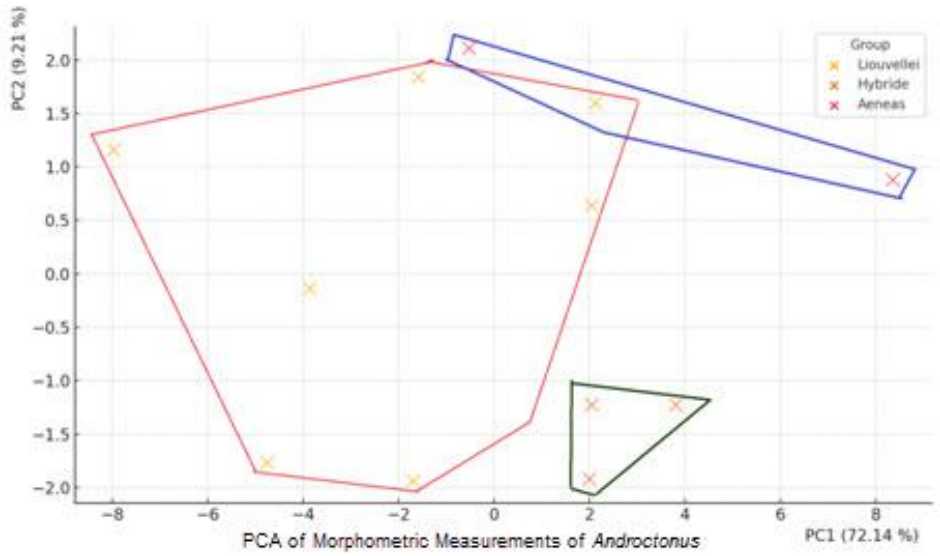

Fig. 9. Factorial plot of the Principal Component Analysis (PCA) showing the projection of individuals on the first two principal axes.

Symbols indicate the groups (*A. liouvellei*, *A. aeneas*, hybrids), and polygons enclose the individuals of each group. PC1 and PC2 explain 72.14% and 9.21% of the total variance, respectively.

PC1 and PC2 (the first two axes of the PCA) alone summarize a very large part of the observed morphometric variance (over 80% in total). The distribution of individuals on the PC1–PC2 plane (Fig. 9) highlights three distinct groups corresponding to the expected categories:

- The individuals of *A. liouvellei* form a relatively homogeneous group, clustered in a specific area of the factor plane (toward the right side of Fig. 9). Their cohesion reflects a high degree of intra-specific morphometric similarity.
- The two individuals of *A. aeneas* appear clearly isolated, at the opposite end of the first axis (PC1), far from the *A. liouvellei* group. This position reflects a marked morphometric divergence of *A. aeneas* from *A. liouvellei*.
- The hybrid individuals occupy an intermediate position between the point clouds of the two parental species. They are located approximately at the centre of the graph, corresponding to a combined or transitional morphological profile. In other

words, the hybrids exhibit intermediate character values, confirming their intermediate morphometric status.

Hierarchical Cluster Analysis (HCA)

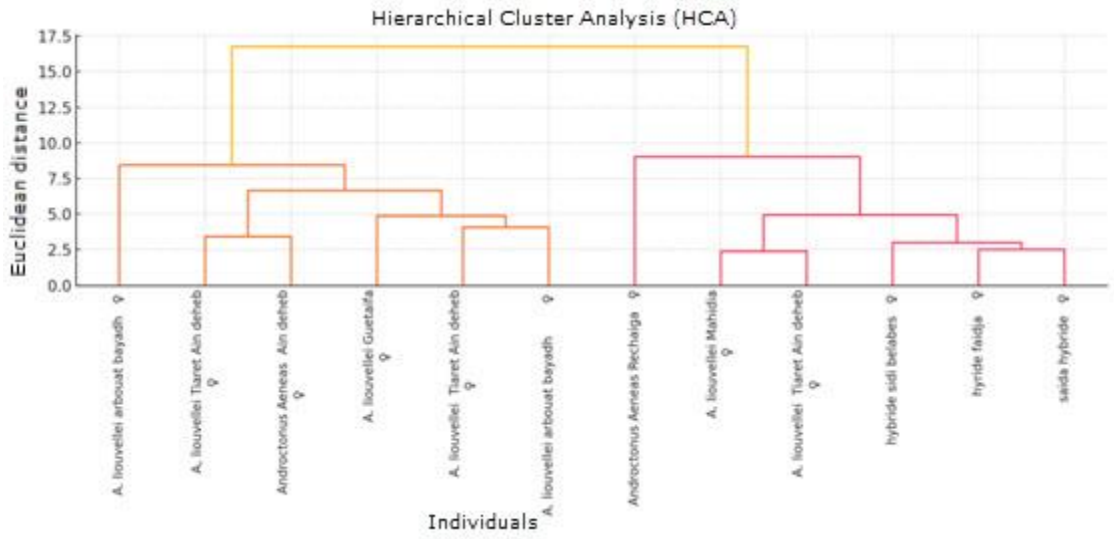

Fig. 10. Hierarchical clustering dendrogram (Ward's method) based on all standardized morphometric variables. Individuals are identified by their group (*A. liouvellei*, Hybrid, or *A. aeneas*) and their locality. The horizontal scale represents morphometric distance. The clusters highlight the grouping of individuals within the same group and the dispersion of hybrids among them.

The hierarchical classification (Fig. 10) largely corroborates the observations from the PCA. The resulting dendrogram shows that:

- **Grouping by species:** The female *A. liouvellei* mostly cluster together within a single, homogeneous group (orange branch in Fig. 10), reflecting their morphometric similarity. In contrast, the two *A. aeneas* individuals form separate, isolated branches (distinct individuals in red), confirming that they are morphologically divergent from the others.
- **Position of the hybrids:** The hybrid individuals do not form a single cluster. They are dispersed across different parts of the dendrogram: some hybrids are closer to the *A. liouvellei* cluster, while others remain relatively isolated or positioned midway between the two species. This varied distribution of the hybrids reflects the variability in their morphometric profiles and the lack of strict uniformity among them.

  It should be noted that the dispersion of hybrids in the dendrogram could be explained by several non–mutually exclusive factors: (i) a multiple or recent hybrid origin, with each hybrid exhibiting a slightly different genetic/morphological combination depending on the parents involved; (ii) morphological instability due to the absence of complete stabilizing selection in the hybrid zones; or (iii) the influence of the local environment, which may enhance certain morphometric traits in hybrids from different localities.

Intergroup statistical comparisons (Kruskal-Wallis and ANOVA)

Kruskal-Wallis tests were performed for each morphometric variable to determine which ones show significant differences among the three groups. **The detailed results of**

the Kruskal-Wallis test for all variables are presented in Table (4). The variables are sorted in ascending order of p-value (from most significant to least significant) to facilitate the identification of the most discriminant traits.

Table 4. Results of the Kruskal-Wallis test comparing *A. liouvellei*, hybrids, and *A. aeneas* for each variable. The table shows the Kruskal-Wallis statistic (approx. H, df = 2) and the associated p-value. Values with $p < 0.05$ are shown in **bold** (significant difference).

Variable	KW Statistic	*p*-value
Metasomal segment II width	7.20	0.03
Metasomal segment II length	6.99	0.03
Carapace posterior width	6.43	0.04
Carapace anterior width	5.75	0.06
Telson length	5.15	0.08
Metasomal segment III length	4.95	0.08
Telson width	4.83	0.09
Metasomal segment IV width	4.82	0.09
Metasomal segment I length	4.54	0.10
Femurlength	4.38	0.11
Metasomal segment IV length	4.12	0.13
Carapace length	3.51	0.17
Metasomal segment I width	3.51	0.17
Chela length	3.50	0.17
Chela width	3.26	0.20
Patella width	3.12	0.21
Metasomal segment III width	2.92	0.23
Metasomal segment V width	2.65	0.27
Mesosoma length	2.47	0.29
Metasomal segment V length	2.43	0.30
Patella length	2.07	0.36
Movable finger length	1.86	0.40
Femur width	1.63	0.44

The variables with the lowest p-values (i.e., the highest test statistics) are the most likely to significantly differentiate the groups. According to Table (2), three morphometric characters stand out as showing significant differences at the 5% significance:

- **Width of metasomal segment II** ($p \approx 0.03$) – The most significant variable,
- **Length of metasomal segment II** ($p \approx 0.03$),
- **Posterior width of the carapace** ($p \approx 0.04$).

An additional variable, the anterior width of the carapace, shows a difference close to the significance threshold ($p = 0.06$). The other measurements do not indicate statistically significant differences between *A. liouvellei*, *A. aeneas*, and the hybrids (their p-values being greater than 0.05), although some show trends that may warrant further exploration (e.g. telson length and segment III length with $p \approx 0.08$–0.09).

The plots in Fig. (11) visually confirm that these four morphometric characters partially differentiate the groups. For example, *A. liouvellei* shows, on average, higher values than *A. aeneas* for carapace width (both anterior and posterior) and the width of metasomal segment II. The hybrids display intermediate values for these measurements; however, they appear closer to *A. liouvellei* for the width of metasomal segment II, while

for anterior carapace width their values are slightly higher than those of *A. aeneas*. It is worth noting that the range of the hybrid boxes is relatively large for some variables despite the modest sample size, reflecting notable intra-group variability among the hybrids.

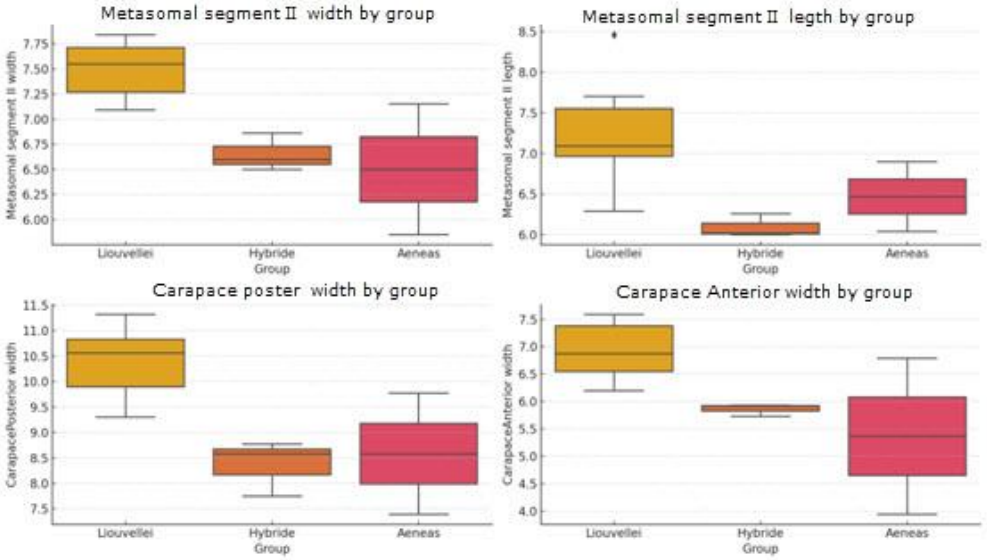

Fig. 11. Boxplots of the four most discriminant variables identified (from left to right and top to bottom: width of metasomal segment II, length of metasomal segment II, posterior width of the carapace, and anterior width of the carapace). Each box represents the distribution of values for a group (*A. liouvellei* in orange, hybrids in brown, *A. aeneas* in red). The median is indicated by a horizontal line, and the ranges (including possible outliers) illustrate intra-group variability.

In addition to the Kruskal-Wallis test, a one-way ANOVA identified a very similar set of discriminant variables. Indeed, the same three variables were significant in the ANOVA (at $\alpha = 0.05$): the width of metasomal segment II, posterior carapace width, and the length of metasomal segment II. Table (5) below summarizes the ANOVA results for these characters. The F and p values indicate a significant difference between at least two groups in each case, confirming the conclusions of the non-parametric test. For reference, other variables fall just below the significance threshold in the ANOVA, notably anterior carapace width ($p = 0.0614$) and metasomal segment I width ($p = 0.0670$), also suggesting trends worth further exploration.

Table 5. Variables showing significant differences between groups according to ANOVA ($\alpha = 0.05$). For each variable, the F statistic (df = 2.9) and the p-value are indicated. Differences are considered significant for $p < 0.05$.

Variable	*F* (ANOVA)	*p*-value	Significance
Metasomal segment II width	7.51	0.0121	Yes
Carapace posterior width	7.50	0.0121	Yes
Metasomal segment II length	4.51	0.0441	Yes

The ANOVA results therefore align with those of the Kruskal-Wallis test. They confirm that the width of metasomal segment II, the posterior width of the cephalothorax (carapace), and the length of metasomal segment II are key morphometric criteria for distinguishing female *A. liouvellei*, *A. aeneas*, and hybrids.

To explore further, a post-hoc Tukey HSD test was applied to these significant variables to identify which specific pairs of groups differ. Table (6) presents the pairwise comparisons that revealed significant differences ($\alpha = 0.05$) according to the Tukey test.

Table 6. Significant pairwise comparisons (Tukey HSD test) for the discriminant morphometric variables. Only comparisons with $p < 0.05$ are listed.

Variable	Comparison	*p-value*	Conclusion
Metasomal segment II width	*A. aeneas* vs *A. liouvellei*	0.0309	Significant difference
Metasomal segment II width	*Hybrids* vs *A. liouvellei*	0.0336	Significant difference
Carapace posterior width	*Hybrids* vs *A. liouvellei*	0.0187	Significant difference
Metasomal segment II length	*Hybrids* vs *A. liouvellei*	0.0461	Significant difference

The Tukey test results indicate that, for the selected variables, the significant differences mainly involve comparisons between *A. liouvellei* and the other two groups. Specifically: The width of metasomal segment II differs significantly between *A. liouvellei* and *A. aeneas* ($p \approx 0.03$) and between *A. liouvellei* and the hybrids ($p \approx 0.033$). No significant difference is observed between *A. aeneas* and the hybrids for this variable ($p \approx 0.91$, not listed in the table), suggesting that hybrids are not distinguishable from *A. aeneas* in metasoma II width. The posterior width of the carapace is significantly larger in *A. liouvellei* compared to the hybrids ($p \approx 0.0187$), while *A. aeneas* does not differ significantly from *A. liouvellei* at $\alpha = 5\%$ (though a trend is noted, $p \approx 0.064$) nor from the hybrids ($p \approx 0.78$). For the length of metasomal segment II, only the comparison between hybrids and *A. liouvellei* reaches statistical significance ($p \approx 0.046$), with hybrids having, on average, a slightly shorter metasoma II than *A. liouvellei*. Again, no difference is detected between hybrids and *A. aeneas* ($p \approx 0.96$) or between *A. aeneas* and *A. liouvellei* ($p \approx 0.27$) for this measurement.

In summary, the multiple comparison analyses reveal a consistent pattern: the hybrids do not differ significantly from *A. aeneas* for the key identified traits, whereas they are more distinct from *A. liouvellei* (significant differences in several cases). This suggests that, morphometrically, the studied female hybrids tend to resemble *A. aeneas* for certain traits, rather than representing a perfectly intermediate state equidistant between the two parental species.

Linear Discriminant Analysis (LDA)

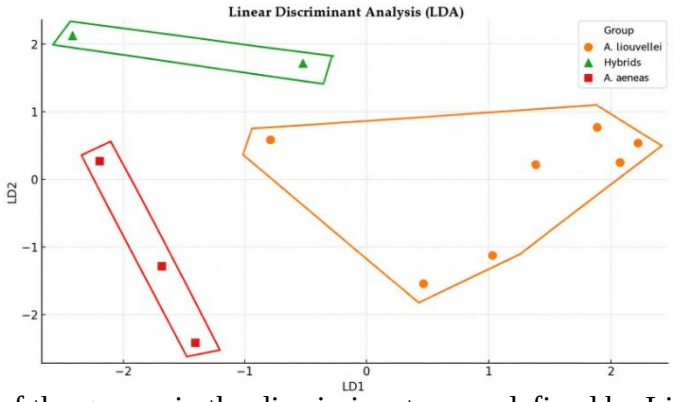

Fig. 12. Position of the groups in the discriminant space defined by Linear Discriminant Analysis (LDA).

The axes LD1 and LD2 are the first two discriminant axes that maximize inter-group separation. Points represent individuals (*A. liouvellei:* orange circles; hybrids: green triangles; *A. aeneas*: red squares), and ellipses illustrate the spread of each group within this space.

The Linear Discriminant Analysis (LDA), based on all morphometric variables, confirms a clear separation between the three groups (Fig. 12). The two main discriminant axes (LD1 and LD2) successfully distinguish *A. liouvellei*, *A. aeneas*, and the hybrids, grouping individuals of the same category closely while keeping the groups distinctly apart. In particular:

- **Separation of parental species:** *A. liouvellei* and *A. aeneas* occupy clearly distinct positions within the space defined by LD1 and LD2. The distance separating them along LD1 reflects the substantial morphological divergence between these two species.
- **Position of hybrids:** The hybrid individuals cluster in an intermediate region of the discriminant space, but their point cloud is slightly shifted toward the *A. aeneas* group. In other words, although the hybrids are intermediate, they appear somewhat closer to *A. aeneas* than to *A. liouvellei* in the LDA projection. This observation aligns with the post-hoc test results: hybrids may share more morphometric similarities with *A. aeneas.* Several factors could explain this affinity, including a genetic dominance effect of *A. aeneas* traits in the cross (e.g. if the father is *A. aeneas*), or developmental/environmental influences shaping the hybrid phenotype toward *A. aeneas*. In any case, the hybrids remain distinct as a group, occupying a unique position in the discriminant space that reflects their particular combination of traits.

It should be noted that the LDA, by maximizing group separation, highlights the variables that contribute most to discrimination. Unsurprisingly, these are primarily the traits already identified—metasomal and carapace dimensions—reinforcing the importance of these morphometric parameters in distinguishing the three groups.

Discussion

Morphometric Intermediacy of Hybrids: All analyses consistently indicate that the female hybrids exhibit a morphometric profile intermediate between *A. liouvillei* and *A. aeneas*. In the PCA, hybrids occupy a central position between the point clouds of the two parental species, visually confirming their intermediate status. This intermediate position suggests additive inheritance for many morphometric traits: each hybrid generally expresses values falling between those of *A. liouvillei* and *A. aeneas*, reflecting contributions from both parents.

Furthermore, this intermediacy may also indicate incomplete evolutionary divergence. For example, if hybrids originate from populations still undergoing differentiation, their traits may not yet be fully stabilized by natural selection. This could explain the observation of intermediate values and potentially higher variability among hybrids.

Affinity with *A. aeneas*: A notable finding of this study is that, for certain key traits, the hybrids appear to be closer to *A. aeneas* than to *A. liouvillei*. Indeed, multiple comparison tests (Tukey) revealed no significant differences between hybrids and *A. aeneas* for the discriminant characters, whereas the hybrids significantly differed from *A. liouvillei* for these same traits. Furthermore, the discriminant analysis positions the hybrid group nearer to the *A. aeneas* centroid in LD space, reinforcing the idea of a stronger morphometric affinity with *A. aeneas*.

This bias toward *A. aeneas* could be explained by several mechanisms. For example, alleles conferring smaller sizes (since *A. aeneas* is generally smaller for several dimensions) may be dominant, or the initial cross may have involved ♂ *aeneas* × ♀ *liouvillei*, implying maternal and developmental effects that shift the hybrid phenotype toward the father (*A. aeneas*). It is also possible that the hybrids studied originate from areas where *A. aeneas* exerts a stronger genetic influence through asymmetric gene flow. Nevertheless, despite this tendency, the hybrids maintain their own distinct traits and do not fully overlap with *A. aeneas*.

Discriminant Traits: Our analysis identified several morphometric traits that could be used to distinguish hybrids from each parental species. In particular, measurements related to the size of the metasoma (length and width of the second segment) and the width of the cephalothorax (anterior and posterior carapace width) emerge as reliable indicators of differentiation.
These results suggest that, in the context of natural hybridization between *A. liouvillei* and *A. aeneas*, these anatomical regions should be prioritized when detecting signs of morphological introgression or classifying specimens of uncertain origin. For instance, an individual displaying intermediate values for the width of metasomal segment II and carapace width can reasonably be suspected of hybrid origin.
Conversely, traits such as mesosoma length or appendage size (legs, pedipalps) do not appear to differ significantly between groups. This indicates that these features are either less affected by divergence between the species or by hybridization, or that a larger sample size may be required to detect subtle differences.

Variability and Limitations
The hybrids exhibit notable within-group variability for certain traits (Fig. 11, boxplot dispersions), despite their small sample size. This intra-group heterogeneity could reflect diverse origins of the hybrids (multiple independent hybridization events) or simply natural variability due to limited sampling.
Among the pure species, *A. liouvillei* appears relatively homogeneous morphometrically, whereas *A. aeneas* shows considerable variation between its two individuals (notably in carapace length, where one female was considerably smaller than the other). This discrepancy could result from differences in age or growth conditions, or indicate that *A. aeneas* possesses greater intraspecific variability than previously anticipated.
In any case, it is important to note that the very small sample size sparticularly only two specimens of *A. aeneas* limit the statistical power of some conclusions. For example, the low statistical power prevents the use of more robust multivariate analyses, such as ANOVA, to test overall group differences. Therefore, the results obtained should be regarded as indicative trends that require confirmation with additional data.

Evolutionary Implications: The results provide valuable insight into the dynamics of hybridization between *A. liouvillei* and *A. aeneas*. The fact that hybrids exhibit intermediate traits, with a slight predominance of *A. aeneas* characteristics, could indicate directional gene flow or differential selection. For instance, if certain traits inherited from *A. liouvillei* are disadvantageous in the contact zone, hybrids may tend to resemble *A. aeneas* more closely, which could be the locally favoured species.
Alternatively, hybrids may primarily result from crosses involving *A. aeneas* fathers, which would statistically bias the expression of their traits toward *A. aeneas*.
From a taxonomic perspective, the ability to morphometrically distinguish hybrids indicates that, despite gene exchange, the two parental species maintain distinct

phenotypic identities. However, the presence of viable and relatively frequent hybrids raises questions about the permeability of reproductive barriers between *A. liouvillei* and *A. aeneas*, prompting further investigation into whether these hybrid forms are transient (eliminated by selection) or represent stable populations integrated into their environment.

Conclusion

Before delving into the results, it is worth noting that the study of natural hybrids among scorpion species is a rare and important topic for understanding evolutionary dynamics and morphological boundaries between species, as such studies can reveal the shape and genetic changes resulting from natural hybridization. New distribution points for *Androctonus liouvillei* (Fig. 8) have also been added, and this study is considered a continuation of the previous article on *Androctonus* in Algeria, enhancing our geographical and ecological understanding of this species. Additionally, a map illustrating the distribution of both species has been included, highlighting areas where hybrids appear, particularly in the sympatry (Fig. 13).

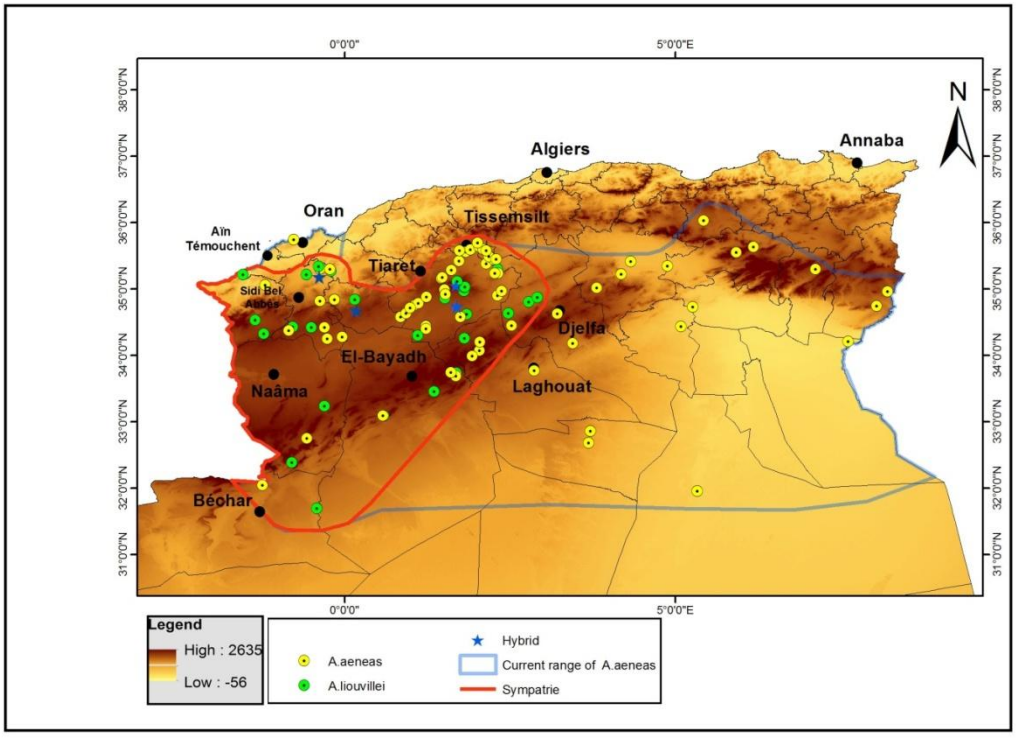

Fig. 13. Map illustrating the sympatric zones and altitudinal distribution of *Androctonus liouvillei*, *A. aeneas*, and their hybrids in Algeria.

This morphometric study highlights several key findings. Female hybrids between *A. liouvillei* and *A. aeneas* exhibit an intermediate phenotype that combines characteristics of both parental species; however, for several important morphological dimensions, particularly those of the metasoma and the carapace, hybrids tend to resemble *A. aeneas* more closely. In addition, certain morphometric parameters show strong discriminative power among the studied groups, especially the length and width of the second metasomal segment as well as the width of the carapace. These traits clearly distinguish *A. liouvillei*, *A. aeneas*, and their hybrids, and may therefore serve as useful diagnostic criteria in future studies. Hierarchical analysis also indicates that hybrids do

not form a uniform group but instead display considerable morphological variability, with some individuals appearing morphologically closer to *A. liouvillei* while others appear more isolated. This pattern may reflect diverse hybridization histories or the influence of local environmental conditions.

Moreover, detailed morphological data for *A. liouvillei* have been added, accompanied by an illustrative figure. The diagnostic differences between *A. liouvillei* and *A. aeneas* are also presented in a separate section to facilitate clear identification and differentiation of the two species. Overall, these results provide a solid basis for discussing the dynamics of natural hybridization between the two species, suggesting that despite potential genetic exchange, distinct morphological differences persist and can be quantitatively measured. Further research with larger sample sizes and ideally including genetic data would help confirm these trends, estimate gene flow between populations, and assess the long-term viability of hybrids. Ultimately, such studies contribute to a deeper understanding of introgression processes, the permeability of species boundaries to hybridization, and the taxonomic validity of populations in an evolutionary context where species limits may be more fluid than previously assumed.

Acknowledgments

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First record of predation of *Leiurus arabicus* on *Androctonus crassicauda* in King Abdulaziz Royal Reserve, Saudi Arabia

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Abstract

Intraguild predation represents an important ecological interaction that influences species composition and trophic relationships in arid ecosystems. During diurnal surveys in the King Abdulaziz Royal Reserve (KARR), Saudi Arabia, we documented a case of predation involving two buthid scorpions. Specifically, an individual of *Leiurus arabicus* was observed preying on *Androctonus crassicauda* on sandy soil with scattered rocks. When disturbed, the predator attempted to retreat into rock crevices while firmly holding its prey, demonstrating strong prey-retention behaviour. This observation highlights predator–predator interactions within Buthidae in Saudi Arabian desert environments and provides insights into trophic dynamics among sympatric scorpion species.

Keywords: Buthidae, intraguild predation, *Leiurus arabicus*, *Androctonus crassicauda*, KARR, Saudi Arabia.

Introduction

Intraguild predation (IGP) occurs when species within the same ecological guild both compete and prey upon each other (Polis *et al*., 1989; Rosenheim *et al*., 1995). It is widespread across taxa, including insects, fish, crustaceans, and mites, and is influenced

by size or developmental stage. IGP affects population dynamics, community structure, and biological control outcomes. Consequently, it is a key focus in studies of predator–predator interactions (Wise, 1993; Schausberger & Walzer, 2001; Onzo *et al.*, 2005).

Scorpions are venomous, opportunistic predators capable of capturing a wide range of prey, including arthropods and small vertebrates (Polis, 1990; McCormick & Polis, 1990). Notably, their diet may also include other predatory arthropods, such as spiders, myriapods, and even conspecific or heterospecific scorpion species, underscoring the occurrence of intraguild predation within this group (McCormick & Polis, 1990).

The genus *Leiurus* was thoroughly revised by Lowe *et al.* (2014), revealing the presence of three distinct species distributed across different regions of Saudi Arabia. Consequently, all previous records of *Leiurus quinquestriatus* (Ehrenberg, 1828) from the Kingdom were reassigned to these species: *Leiurus brachycentrus* (Ehrenberg, 1829), occurring along the southern Red Sea coast of Saudi Arabia and Yemen; *Leiurus arabicus* Lowe, Yağmur & Kovařík, 2014, found in central Arabia and extending southwest to Makkah; and *Leiurus haenggii* Lowe, Yağmur & Kovařík, 2014, distributed along the Red Sea coastal mountains, reaching into Yemen and western Oman (Lowe *et al*., 2014).

Material and Methods

The study was conducted in the King Abdulaziz Royal Reserve, located north of Riyadh, Saudi Arabia. This reserve is among the three largest in the country, covering an area of 28,345 km², and includes a variety of habitats ranging from gravel plains and sand dunes to mountainous areas and wetlands (Altalhi *et al*., 2025) (Fig. 1). This habitat diversity has resulted in remarkable biological diversity, including arachnids, currently, the authors indicate that the total number of scorpion species recorded in Saudi Arabia reaches 37 species (Lowe *et al*., 2014; Alqahtani *et al*., 2019; Yağmur *et al*., 2025).

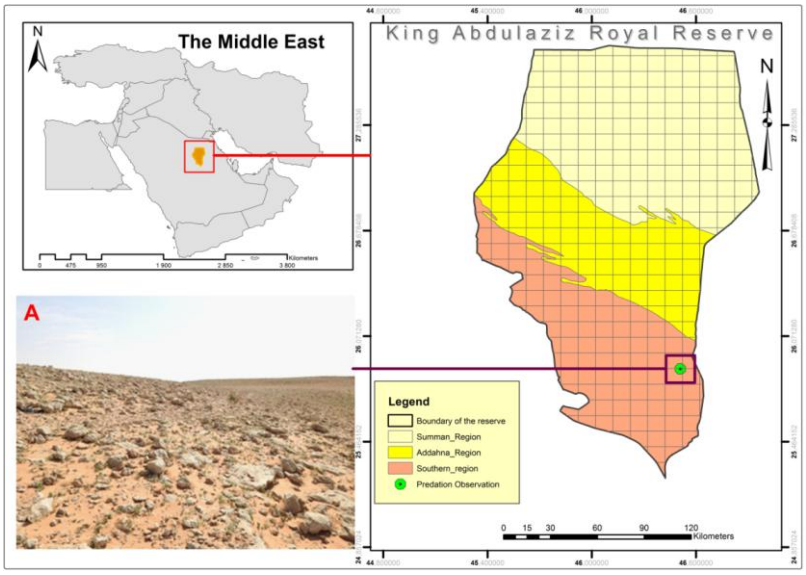

Fig. 1. Predation location map. A. habitat of the predation (Sandy substrate with scattered rocks).

Several methods have been proposed for studying scorpions (Dehghani *et al*., 2016, 2019). In the present study, as sampling was conducted in February, we adopted the shelter-search technique, which meant looking under rocks during daytime surveys.

Results and Discussion

The predation event was recorded during a diurnal survey conducted on 2 February 2026 between 12:00 and 16:00 h, the observation occurred on sandy soil with scattered rocks near a wadi in the King Abdulaziz Royal Reserve (25°53′0.63″N, 46°30′32.40″E, 610 m a.s.l.), Saudi Arabia (Fig. 2). The predator and its prey were collected and preserved in 70% ethanol. The specimens were subsequently identified, and the prey was confirmed as the Arabian fat-tailed scorpion, which is extremely dangerous scorpion usually found in the Middle East (Yağmur *et al*., 2008).

Fig. 2. *Leiurus arabicus* feeding on *Androctonus crassicauda*.

In the King Abdulaziz Royal Reserve, Saudi Arabia, the deathstalker, *Leiurus arabicus*, is highly abundant in certain rocky desert habitats, where the Arabian fat-tailed scorpion *Androctonus crassicauda* (Olivier, 1807) also occurs. Both species appear to typify the biotic characteristics of the most arid desert environments within the Saudi Arabian landscape.

The observation reported in this study expands the known range of prey for Middle Eastern scorpions. Additional research is required to acquire more detailed insights into these intraguild predation (IGP) interactions and to better understand their ecological role.

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A case of predation on *Mesalina cryptica* (Squamata: Lacertidae) by *Leiurus arabicus* (Scorpiones: Buthidae) in King Abdulaziz Royal Reserve, Saudi Arabia

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Abstract

An adult buthid scorpion *Leiurus arabicus* Lowe, Yağmur & Kovařík, 2014 was observed preying on the lizard *Mesalina cryptica* (Squamata: Lacertidae) in the King Abdulaziz Royal Reserve (KARR), Saudi Arabia. Predation of *Mesalina* by a scorpion has not been previously documented.

Keywords: Scorpiones, Buthidae, *Leiurus arabicus*, *Mesalina cryptica*, predation, KARR, Saudi Arabia.

Introduction

Scorpions primarily feed on insects and other arachnids; however, larger species may also prey on other invertebrates, small lizards, snakes, and even small mammals such as mice (Vachon, 1952; Kock, 1969; McCormick & Polis, 1990; Dupré, 2015; Sadine, 2018; Sadine & El Bouhissi, 2021; Chedad *et al*., 2022, 2023). Cannibalism and intra-guild predation are also frequently reported across many scorpion species (Lighton *et al*., 2001; Sánchez-Muros *et al.*, 2014; Moreira *et al*., 2022).

Material and Methods

The King Abdulaziz Royal Reserve is one of the largest protected areas in the Kingdom of Saudi Arabia. It was established in 2018 and was added to the Green List of the International Union for Conservation of Nature (IUCN) in 2025 due to its high biodiversity. Geographically, it is located north of Riyadh and covers an area of 28,345 km². The reserve hosts a wide diversity of habitats, ranging from open plains and sand dunes to mountainous areas (Al-Asmari, *et al*., 2025) (Fig. 1).

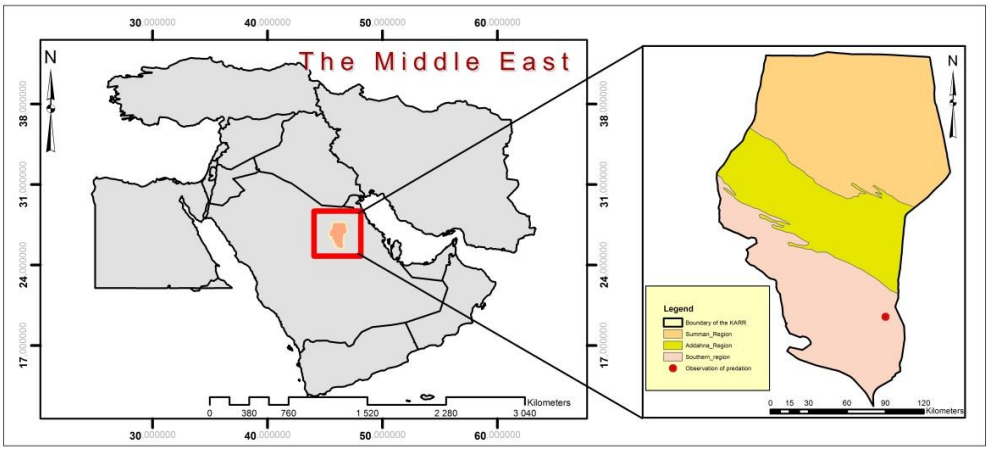

Fig. 1. Geographical location of the study area, Saudi Arabia, showing predation event.

Overturning rocks is a widely used diurnal method for sampling scorpions, as these opportunistic animals frequently shelter in rock crevices and cavities (Dehghani *et al*., 2016). This technique allows researchers to efficiently locate and capture individuals hiding in spaces that match their body size and are inaccessible to larger animals (Nejati *et al*., 2014; Gholizadeh *et al*., 2015).

Results and Discussion

During a recent diurnal sampling trip in February 2026 in the King Abdulaziz Royal Reserve, Saudi Arabia, we recorded a predation event between two endemic species in a rocky area (25°46′20.5967″N, 46°04′17.2452″E; 620 m a.s.l.): an adult buthid scorpion, *Leiurus arabicus*, feeding on the lizard *Mesalina cryptica* (Squamata: Lacertidae), genetically distinct from the *Mesalina guttulata* group (Šmíd *et al*., 2025) (Fig. 2). Their photograph was captured using a smartphone.

The deathstalker, *Leiurus arabicus*, is considered one of the most venomous scorpions worldwide (Van der Meijden *et al*., 2017; Alqahtani & Badry, 2020). This large buthid scorpion, distributed in central Saudi Arabia (Lowe *et al*., 2014), is a nocturnal sit-and-wait predator that primarily feeds on insects and other arthropods, including spiders, centipedes, and occasionally other scorpions (Polis, 1990; McCormick & Polis, 1990; Fet *et al*., 2000).

This is the first documented case of predation on genus *Mesalina* by a scorpion. Nonetheless, several instances of reptile predation by scorpions have been reported, including the predation of the snake *Coronella girondica* by *Buthus occitanus* (Garcia-Cardenette, 2003) and of the lizard *Acanthodactylus* spp. by *Androctonus amoreuxi* (Sadine & El Bouhissi, 2021). In other cases, the roles are reversed, with scorpions serving as prey for reptiles, as observed in the gecko *Ptyodactylus* spp. preying on *Leiurus quinquestriatus hebraeus* (Zlotkin *et al*., 2003), the lizard *Podarcis hispanica*

atrata preying on *Buthus occitanus* (Castilla, 1995), and the lizard *Acanthodactylus boskianus* on *Buthacus tadmorensis* (Shehab *et al*., 2011).

Fig. 2. *Leiurus arabicus* scorpion feeding on lizard *Mesalina cryptica*.

These findings provide a critical baseline for understanding the diet of *Leiurus arabicus* and offer important insights and recommendations for future research aimed at elucidating the behavioural ecology and ecological interactions of this species within its natural habitat.

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Predation of the Sharqiyah Sand Gecko *Trigonodactylus sharqiyahensis* Metallinou & Carranza, 2013 (Squamata: Gekkonidae) by Perez's Huntsman Spider *Eusparassus perezi* (Simon, 1902) (Araneae: Sparassidae) in Oman

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Abstract

We report a predation event involving a subadult Sharkiyah Sand Gecko *Trigonodactylus sharqiyahensis* Metallinou & Carranza, 2013 (Squamata: Gekkonidae) consumed by an adult female of Perez's Huntsman Spider *Eusparassus perezi* (Simon, 1902) (Araneae: Sparassidae) in the Ash Sharqiyah South Governorate of Oman.

Keywords: Arabia, gecko, natural history, predation, Sparassidae, trophic interaction.

Spiders are a diverse group of arachnids, occupying a wide range of habitats, and are primarily recognised for their role as generalist or specialist predators of other invertebrates (Foelix, 2011, 2025). However, some species opportunistically predate vertebrates such as amphibians (Menin *et al*., 2005), birds (Nyffeler & Gibbons, 2022), small mammals (Valdez, 2020), and squamates such as snakes (Nyffeler & Gibbons, 2021) and lizards (Reyes-Olivares *et al*., 2020).

Predation of lizards by spiders is a widely documented phenomenon (Reyes-Olivares *et al*., 2020), with numerous records involving both web-building (e.g. O'Shea & Kelly, 2017; de Luna *et al*., 2020; van Blerk *et al*., 2021) and free-wandering spiders

(e.g. Gómez-Martínez *et al*., 2021; Zdunek & Bandara, 2022; Rakotoarimalala *et al*., 2024).

Lizards serve as both predators and prey within their ecosystems, regulating invertebrate populations and providing sustenance for higher trophic levels, such as birds and mammals (Reilly *et al*., 2007). Equally, spiders are typically dominant predators of most invertebrates but are vulnerable to larger vertebrate taxa. In cases where spiders predate vertebrates, the resulting interaction is noteworthy from both trophic and general natural history perspectives, even more so if the observation(s) are made in understudied regions and/or of taxa whose natural history is poorly known.

Perez's Huntsman Spider *Eusparassus perezi* (Simon, 1902) is a spider recorded across the eastern coasts of the Arabian Peninsula (namely in Oman, the United Arab Emirates, and Yemen), and in Djibouti and Somalia (Simon, 1902; Jäger & Kunz, 2005; Moradmand, 2013; World Spider Catalog, 2026). The Sharqiyah Sand Gecko *Trigonodactylus sharqiyahensis* Metallinou & Carranza, 2013 is endemic to Oman (Metallinou & Carranza, 2013; Carranza *et al*., 2021; Uetz *et al*., 2026).

On 8 February 2026 at 20:57, the first author observed an adult female of *E. perezi* consuming a subadult (sex unverifiable from photographs) of *T. sharqiyahensis* (Fig. 1A-C) in Ash Sharqiyah South Governorate, Oman, at a locality approximately 10 km south of Al Juwairiya (20.94581°N, 58.78398°E). Initial prey capture was not observed, the spider was already consuming the gecko when encountered. To our knowledge, this represents the first documented case of vertebrate predation by *Eusparassus perezi*.

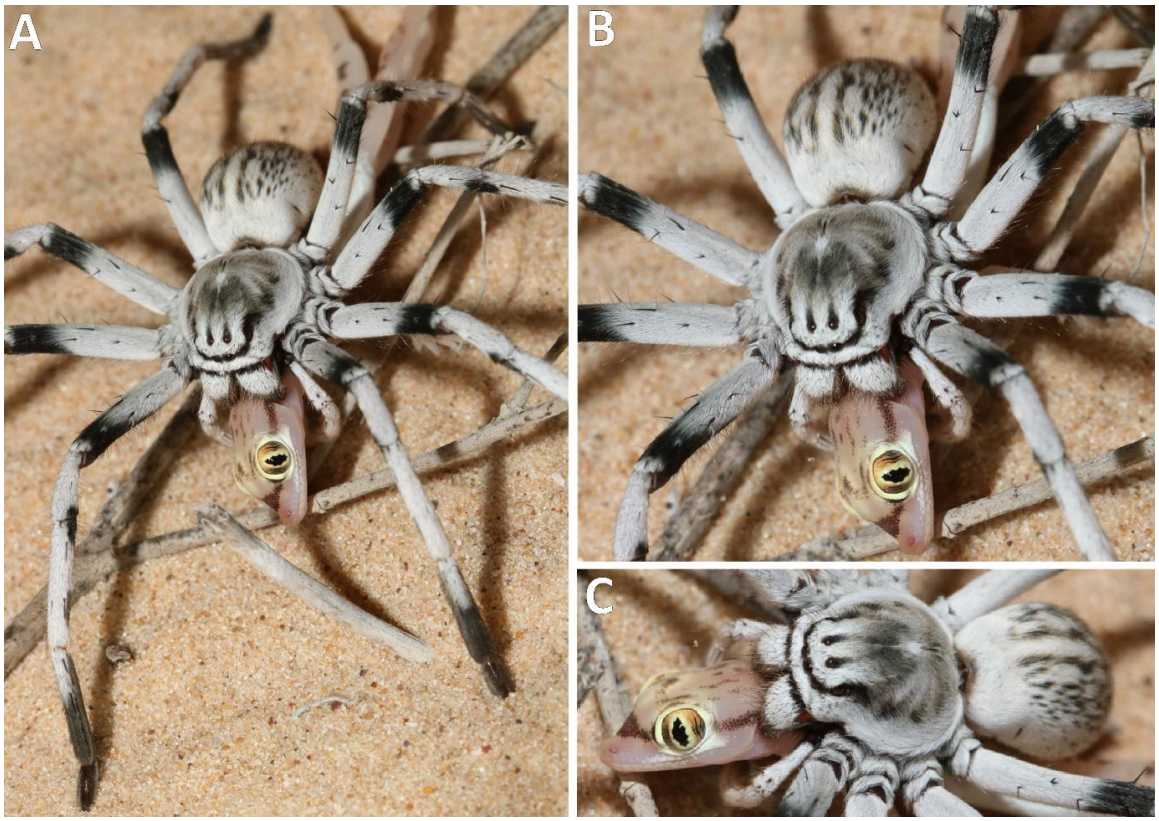

Fig. 1. A subadult of the Sharqiyah Sand Gecko *Trigonodactylus sharqiyahensis* Metallinou & Carranza, 2013 as prey of an adult female Perez's Huntsman Spider *Eusparassus perezi* (Simon, 1902). A. general view of the predation event. B. close-up frontal view. C. close-up dorsal view. Photographs by Thijs Valkenburg.

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First record of the jumping spider *Menemerus marginatus* (Kroneberg, 1875) (Araneae: Salticidae) from Iraq

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Abstract

Menemerus marginatus (Kroneberg, 1875) of family Salticidae is recorded from Iraq for the first time. Adult males and females of this species were collected in October and November in Baghdad province, central of Iraq. Its description, illustrations, and measurements are presented.

Keywords: Araneae, Salticidae, *Menemerus marginatus*, Iraq.

Introduction

Spiders (Order Araneae), under Class Arachnida, form the largest group of this class with 139 families, 4498 genera and 53608 species in the world. Family Salticidae Blackwall, 1841, known as jumping spiders, is geographically cosmopolitan in distribution and contains 697 described genera and 6929 described species (World Spider Catalog, 2025).

Genus *Menemerus* Simon, 1868 is characterized by a flattened prosoma, a broad anterior eye row, and dense fringes of white or silvery setae around the AME. The carapace is low and elongated, with a strongly recurved posterior eye row (PLE–PME), usually broad white areas along lower sides of cephalothorax, the abdominal dorsum typically shows pale transverse patches formed by reflective scales (Wesołowska, 1999). Male palpal morphology is highly diagnostic: the bulb is rounded to oval; the embolus arises anteromedially and is long and slender; the retrolateral tibial apophysis is elongated and often pointed; and the tegular apophysis is prominent. Females exhibit an epigyne

with a broad anterior atrium, short copulatory ducts, and bilobed or spherical spermathecae (Wesołowska, 1999).

A regional comparison of Salticidae diversity across the Middle East demonstrates pronounced differences in the extent of taxonomic knowledge among neighbouring countries. In Iran, comprehensive faunistic surveys and recent revisions have brought the number of documented species to 112 (Zamani *et al.*, 2020). Similarly, in Türkiye, the number of species belonging to Salticidae has increased to 152 (Danışman *et al.*, 2023), reflecting substantial progress in the exploration of its salticid fauna.

By contrast, the current state of knowledge regarding the Salticidae of Iraq remains considerably limited. The most recent updated checklist (2023) lists only 11 species (Al-Khazali *et al.*, 2023), a figure that likely reflects insufficient sampling and limited taxonomic attention rather than actual species scarcity. Notably, the genus *Menemerus* Simon, 1868, widely distributed throughout the region, is represented in Iraq by a single species, *Menemerus animatus* O. Pickard-Cambridge, 1876, according to the available record (Reimoser, 1913).

In this study, we report an additional species of *Menemerus* from Baghdad Province, constituting a new record for the Iraqi fauna.

Material and Methods

The specimens were hand collected from gardens at Baghdad province (Al-Doura, Al-Jadriyah)(Map 1) in daytime, then deposited in 80% ethanol, and examined in laboratory of Ecology department, Science college, Basrah University, by Leica stereomicroscope to identify spiders by accurate keys of Rakov & Logunov (1997) and Wesołowska (1999). The habitus of male and female as well the copulatory organs (epigyne and palps) were photographed by the co-author (Sadeq Mithal Al-Esa) using Sony A7riv camera, with Canon mp-e 65 mm f 2.8 macro lens; epigyne and pediplap photos were taken by Sony a7riv connected to zeiss primo star microscope; the image stacking done by Helicon focus 8.1.0; brightness, sharpness, and colour correction done by Adobe Photoshop CC 2024. Coordinates are measured by Global Positional System instrument, the measurements of legs are provided as total length (femur, patella, tibia, metatarsus, and tarsus). All measurements are in millimetres (mm).

All preserved material has been deposited at the Arthropods Collection of the Natural History Museum of Basrah University, Iraq; ensuring long-term curation and accessibility for future taxonomic studies. Map included in this study was designed by using ArcMAP GIS 10.8 program.

Results

Taxonomy

Family **Salticidae** Blackwall, 1841

Genus ***Menemerus*** Simon, 1868
Menemerus marginatus (Kroneberg, 1875)

Taxonomic references
Marpessa marginata Kroneberg, 1875: 47, pl. 5, f. 34 (D♂♀).
Menemerus marginatus Simon, 1901a: 604.
Menemerus cronebergi Charitonov, 1946: 31, f. 59-60 (D♂).
Menemerus marginatus Prószyński, 1979: 313, f. 201-206 (♂♀).
Menemerus marginatus Nenilin, 1984b**:** 1176 (S of *Menemerus cronebergi*).
For full taxonomic references see World Spider Catalog (2025).

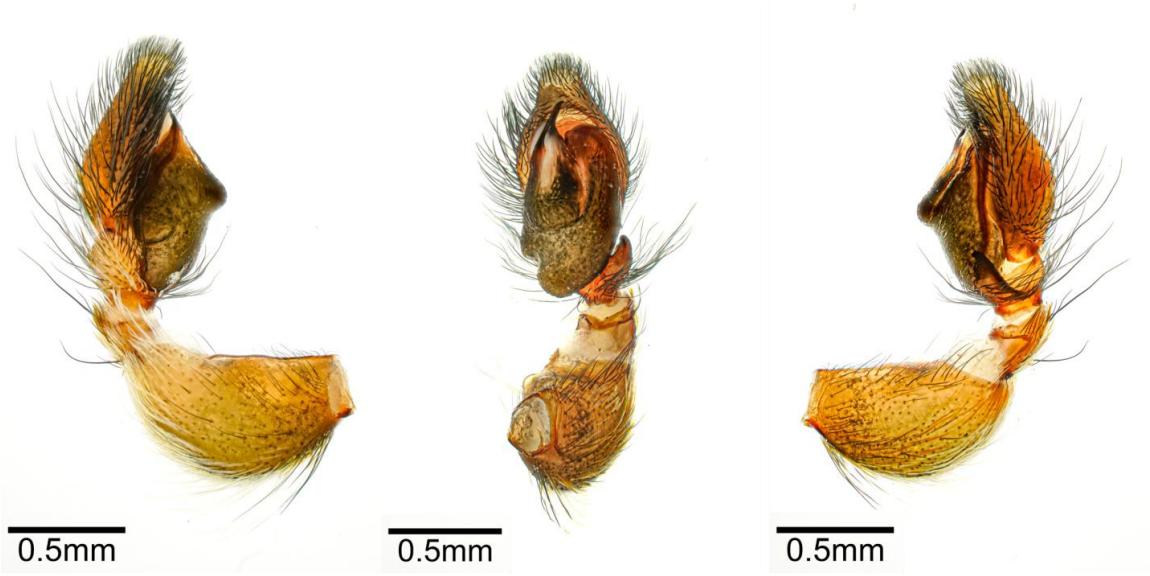
World distribution
Caucasus (Russia, Azerbaijan), Kazakhstan, United Arab Emirates, Iran, Central Asia, Afghanistan, Pakistan, India (World Spider Catalog, 2025).

Material examined: 3♂♂, 5♀♀, Doura district, 33°13'51.91"N, 44°23'14.87"E, (house gardens, collected from crevices of trees), 1♂, 1♀, Al-Jadriyah, 33°16'32.47"N, 44°23'16.62"E, (Gardens of Baghdad University), Baghdad province, central of Iraq, 27-10-2024; 15-11-2025; *leg.* Sadiq Methal Al-Esa.

Description: Male (Fig. 1): total length 5.94 mm, cephalothorax length 2.69 mm, width 2.05 mm, dark brown in colour, a black band on each side, a band of white hairs on the margins, ocular area black with long black bristles, cephalic region black and has very small white hairs, clypeus low. Chelicerae black. Abdomen length 3.35 mm, width 1.49 mm; anterior half of abdomen with a wide, longitudinal, mid-dorsal band, brown with a wavy pattern of lighter setae on either side, posterior half of abdomen with several mid-dorsal, forward-pointing chevrons; with long, dense, white-brown hairs at the anterior margin of the abdomen; ventral side of abdomen with central dark brown chevron. Spinnerets yellowish brown in colour. Palps (Fig. 2) cymbium surrounded by long black hairs and truncated at the anterior tip; single strong sclerotized retrolateral tibial apophysis (RTA) present with broad base; straight embolus with distal lamella.
Female (Fig. 3): total length 7.57 mm, cephalothorax length 3.19 mm, width 2.29 mm; abdomen length 4.15 mm, width 2.39 mm; female resembles male in general appearance except it is slightly larger than male and the ventral side of abdomen of pale white colour without central dark chevron. Epigynum (Fig. 4) distinctly sclerotized round, with an indentation at the posterior edge, large oval pockets near epigastric furrow, strongly sclerotized internal structure including genital pores, short seminal ducts. Spermathecae away from the midline and spherical in shape.

A B

Fig. 1. *Menemerus marginatus* (Kroneberg, 1875) ♂ habitus. A. dorsal view. B. ventral view.



A B C

Fig. 2. *Menemerus marginatus* (Kroneberg, 1875) ♂ pedipalp. A. prolateral view. B. ventral view. C. retrolateral view.

Discussion

Genus *Menemerus* is broadly distributed across the palaearctic region, the Mediterranean Basin, and arid regions of the Middle East, occupying a wide range of habitats including walls, tree, trunks, gardens and human-modified environments (Wesołowska, 1999). Species of this genus are characterized by a set of morphological traits that facilitated reliable taxonomic identification. These include a broad but indistinctly outlined light streak on the cephalothorax and abdomen, large lateral white patches on the lower sides of the prosoma, a sclerotized epigynal plate with paired depressions and in males, a pedipalp with a semicrescent femur, a broad, shortened tibia and well defined RTA that is typically robust and specific. These characters collectively represent stable diagnostic features across the genus and are crucial for distinguishing closely related species (Prószyński, 2024).

Among Middle Eastern salticids, *M. marginatus* is most easily confused with other species of *Menemerus* that share similar dorsal patterns, particularly *M. taeniatus* (L. Koch, 1867) and *M. semilimbatus* (Hahn, 1829). *M. marginatus* is most similar to *M. semilimbatus* and *M. taeniatus*, species that share comparable dorsal abdominal markings and general somatic proportions. However, *M. marginatus* can be reliably distinguished by several consistent morphological features, in *M. marginatus* the anterior dorsal abdominal band is broader witth transitions posteriorly into multiple forward-pointing chevrons, whereas *M. semilimbatus* typically shows a more continuous, less contrasted dorsal pattern. The male palp of *M. marginatus* bears an RTA that is broader at the base and nearly straight distally, unlike the more curved and narrower RTA of *M. semilimbatus.* The epigynum of *M. marginatus* displays large oval depression and laterally displaced spherical spermatheacae in contrast to the more medially positioned spermathecae and narrower depressions in *M. semilimbatus*. *M. taeniatus*, usually exhibits a more sharply delimited dorsal stripe, whereas *M. marginatus* shows a broad but indistinctly outlined light streak along the cephalothorax and abdomen (Wesołowska, 1999).

The male embolus in *M. marginatus* is long, straight and associated with a distal lamella, while *M. taeniatus* generally has a straightly more curved embolus with less

developed lamellar structures. Females of *M. marginatus* possess a rounded, posteriorly indented epigynal plate, whereas *M. taeniatus* features a more elongated epigynal outline with narrower copulatory openings (Tripathi *et al.*, 2021).

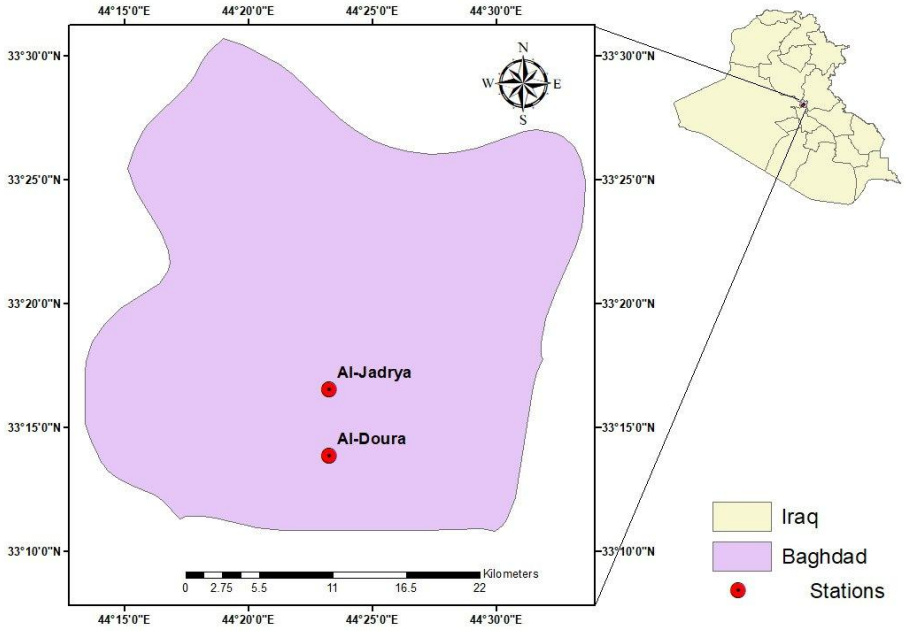
A B

Fig. 3. *Menemerus marginatus* (Kroneberg, 1875) ♀ habitus. A. dorsal view. B. ventral view.

A B C

Fig. 4. *Menemerus marginatus* (Kroneberg, 1875) ♀ epigynum. A. intact, ventral view. B-C. separated and cleared. B. ventral view. C. dorsal view.

The Salticidae of Iraq remain poorly documented compared to neighbouring countries. While Türkiye and Iran currently list more than 100 salticid species each, reflecting decades of continuous survey effort, Iraq has only recently begun to accumulate updated taxonomic data. The record of *M. marginatus* presented here increases the number of documented *Menemerus* species in Iraq from one (*M. animatus*) (Reimoser, 1913) to two, highlighting the underexplored nature of the Iraqi salticid fauna. Given the wide distribution of *Menemerus* species in adjacent regions, it is highly probable that additional species occur in Iraq but remain uncollected due to limited sampling, especially in rural and semi-arid environments where many salticids thrive.



Map 1. Collecting locations of *Menemerus marginatus* (Kroneberg, 1875) in Iraq.

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A new species of jumping spider genus *Phintella* Strand, 1906 from Bangladesh (Araneae: Salticidae: Chrysillini)

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Abstract

A new species of jumping spider *Phintella unidentata* sp. n. of the family Salticidae is recorded and described from Khulna, Bangladesh. Distribution is provided together with the description of the species.

Keywords: Jumping spider, Araneae, Salticidae, Chrysillini, *Phintella*, Bangladesh.

Introduction

Family Salticidae (Jumping spiders) is one of the largest, attractive, widespread and cosmopolitan group of jumping spiders. The family at present is composed of over 6800 valid species belonging to about 700 genera in the world fauna (World Spider Catalog, 2026). All these are important predatory components of insect pests in the crop-fields, gardens and forests. Members of the genus *Phintella* Strand are commonly distributed to majority of the South Asian countries but few records are found in the fauna of Bangladesh (Chowdhury & Pal, 1984; Okuma *et al.*, 1993; Biswas, 2009, 2019, 2025). These are very small, metallic, attractive and colourful but do not make any web in their habitat. They are quick jumper, busy, and found to move 'to and fro' on the leaves and twigs of shrubs in searching prey. They are one of the important biological control agent of garden crop pests.

Genus *Phintella* was first erected by Bösenberg and Strand in 1906 with the type-species *Telamonia bifurcilinea* (Böesenberg & Strand, 1906). At present, the genus composed of 88 valid species worldwide (World Spider Catalog, 2026). Records of these spiders in Indian Sub-continent and other Asian countries are satisfactory (Żabka, 1985; Chen & Zhang, 1991; Prószyński, 1992; Barrion & Litsinger, 1995; Lei & Peng, 2013;

Caleb, 2014; Huang *et al.* 2015; Luong *et al.*, 2016; Roy *et al*., 2016; Dhali *et al.*, 2017; Luong, 2017; Peng, 2020; Hoang *et al.*, 2023; Wang *et al.*, 2023; Sudhin *et al.*, 2023, 2024) but in Bangladesh, only three species are recorded (including the present one) (Okuma *et al.*, 1993; Biswas, 2009, 2019, 2025). The present paper represents taxonomic description of a new species *Phintella unidentata* sp. n. together with its distribution.

Material and Methods

The specimens of this study were collected by jerking the branches of shrubs on an inverted umbrella placed underneath the plants from Khulna Zilla School campus, Khulna, Bangladesh. After sorting, the specimens were preserved primarily in 70% ethyl alcohol and after identification, they were separately preserved in Audmasn's Preservatives following Lincoln & Sheals (1979). The preserved specimens are currently in the collection of the Department of Zoology, Khulna Govt. Womens' College, Khulna, Bangladesh and will be deposited to the Museum of the Department of Zoology, University of Dhaka, Bangladesh, in due course of time.

All the necessary body-parts of the specimens (viz. – chelicerae, maxillae, labium, pedipalps etc.) are dissected out and illustrated under Stereozoom Binocular Microscope. All measurements are taken in millimetres (mm). Leg measurements are given in the following sequence: femur, patella, tibia, metatarsus, tarsus, and total length.

Identification references consulted are: Tikader (1987), Żabka (1985), Prószyński (1992), Barrion & Litsinger (1995), Fuhn & Gherasim (1995), Okuma *et al*. (1993), Biswas (2009, 2025), Caleb (2014), Roy *et al.* (2016), Luong (2017), Peng (2020), and Sudhin *et al.* (2024).

Results

Taxonomy

Family **Salticidae** Blackwall, 1841
Subfamily **Salticinae** Blackwall, 1841
Tribe **Chrysillini** Simon, 1901
Genus ***Phintella*** Strand, 1906
Type-species ***Phintella bifurcilinea*** (Bösenberg & Strand, 1906)

Distribution of *Phintella* species: India, Srilanka, China, Myanmar, Vietnam, Japan, Malayasia, Singapore, and Indonesia.

***Phintella unidentata* sp. n.**
(Figs. 1a-f)

Material examined: Holotype: 1 male. Paratype: 1 male. both are collected from the same locality (Khulna).

Type-locality: Bangladesh: Khulna Zilla School garden, Khulna; dates: 17.II.2022 and 18.XII.2022, Coll. V. Biswas. Types are at present in the collection of the Department of Zoology, Khulna Govt. Womens' College, Khulna and will be deposited to the Museum of the Department of Zoology, University of Dhaka, Bangladesh.

Description of the male (Fig. 1a**):** Body small, metallic brownish-yellow; cephalothorax brownish, legs and abdomen light yellowish. Total body length 4.10 mm. Carapace 2.00 long and 1.65 wide; abdomen 2.10 long and 1.30 wide.

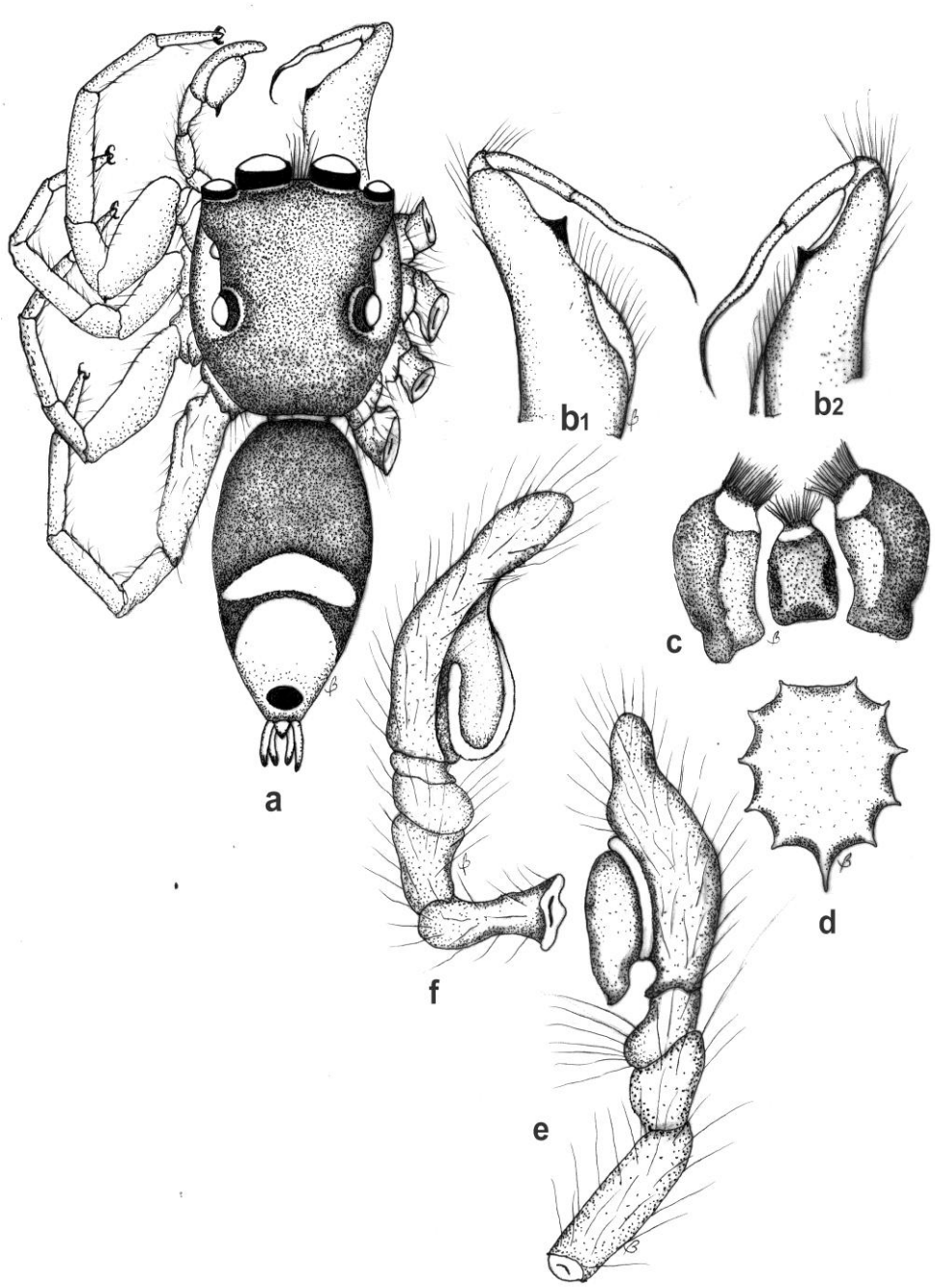

Fig. 1. *Phintella unidentata* sp. n. a. Whole body, dorsal view. b1-b2. Chelicerae. c. Maxillae and labium. d. Sternum. e-f. Male palp. e. lateral view. f. ventrolateral view.

Cephalothorax: Broad, robust, nearly squarish, anterior region high and enlarged; anterior margin nearly straight, blackish, dorsum with 2 lateral, longitudinal, white bands below the lateral eyes. Eyes unequal, pearly-white, each encircled with black basal bands; anterior row of eyes faintly recurved with anterolaterals distally placed; anteromedians (AME) two times larger than the anterolaterals (ALE); 2nd row of eyes or posteromedians

(PME) minute, brown, placed little far from anterior row in between antero- and posterolaterals; posterior row of eyes (PLE) larger than the posteromedians (PME), straight and placed marginally. Ocular trapezium nearly rectangular (Fig. 1a). Eye diameters: AME 0.48, ALE 0.27, PME 0.08, PLE 0.18; Inter eye-distance: AME-ALE 0.03 ; PME-PME 0.71; PME-PLE 0.14; PLE-PLE 0.87; ALE-PLE 0.52; AME-AME 0.04. Chelicerae long, brown, basally wide, curved behind, 0.57 long, with only one retromarginal tooth (Fig. 1b1-b2). Maxillae and labium longer than wide, brownish in colour and scopulated anterioirly (Fig. 1c). Sternum light brown, nearly globular, anterior margin little concave and posteriorly pointed (Fig. 1d). Male palps are simple, cymbium curved, uniform in shape with tegulum enlarged and sperm duct curved (Figs. 1e-f). Legs long and slender; leg I large, brown, robust with femur enlarged; leg formula 4132 and the measurements of different leg segments (in mm) are shown in Tabl (1).

Table 1. Measurements (mm) of leg segments of *Phintella unidentata* sp. n.

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	0.96	0.35	0.92	0.62	0.42	3.27
II	0.67	0.27	0.81	0.61	0.36	2.72
III	0.78	0.35	0.94	0.62	0.37	3.06
IV	0.98	0.38	0.94	0.65	0.44	3.36

Abdomen: Oval, longer than wide, metallic blue-green with two white bands, posteromedially broader, terminally with a black spot, clothed with brown, erect hairs and pubescence; ventrally pale-brown; spinnerets longer.
Female: Unknown.
Etymology: The species is named due to the presence of only one retromarginal tooth on the chelicerae.

Diagnosis: The present species *P. unidentata* sp. n. appears close to *P. bidentata* Biswas, 2025 and *P. vittata* (C.L. Koch, 1846) in general appearance but it stands distinct in having the following characters:
(1). Position and arrangement of eyes are little similar to those of above species but their structures are quite different,
(2). Cephalothorax more wider than *P. vittata* (C.L. Koch) and *P. bidentata* Biswas,
(3). Structure and dentition of chelicerae are quite different,
(4). Structure of maxillae, labium and sternum different and
(5). Structure of palpal organs of *P. unidentata* sp. n. also differs with those of *P. bidentata*, *P. vittata* and its other Indian congeners and species known from elsewhere (Żabka, 1985; Chen & Zhang, 1991; Prószyński, 1992; Barrion & Litsinger, 1995; Fuhn & Gherasim, 1995; Caleb, 2014; Huang *et al.*, 2015; Peng, 2020; Sudhin *et al*., 2023; and Wang *et al.*, 2023).

Therefore, *P. unidentata* sp. n. is described as new to science.

Acknowledgments

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Biodiversity in Balance: The role of sacred grove and agroecosystems in sustaining spider populations

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Abstract

Spiders are active predators that play a vital role in regulating insect populations and maintaining ecological balance. This study investigates the diversity and distribution of spider communities across three contrasting ecosystems: a traditional Sacred grove**,** Cashew orchards**,** and Banana plantations. Standard biodiversity indices, including species richness, Shannon index, Simpson index, and Evenness, were employed to assess community structure. Results revealed that the Sacred grove harboured the highest species richness (92 species) and diversity (Shannon index 4.371; Simpson index 0.986), with near uniform evenness (0.967). The beta diversity by Bray-Curtis and Sørensen similarity indices revealed clear and consistent patterns of community overlap among the three habitats. The Sacred grove and Cashew plantation exhibited the highest similarity in both abundance-based (Bray-Curtis: 0.594) and presence/absence-based (Sørensen: 0.400) assessments, indicating substantial species sharing and comparable community structure. Conversely, the Banana plantation demonstrated the lowest Bray-Curtis similarity (0.472), suggesting pronounced differences in species abundance relative to the other habitats. Nonetheless, the moderate Sørensen similarity values obtained between the Banana plantation and the remaining habitats (0.286 – 0.400) suggest the presence of shared species, although these were comparatively less abundant. Indicator species analysis did not identify any species with statistically significant habitat associations, likely reflecting low occurrence frequencies and limited site-level replication.

Keywords: Araneae, Comparison, Diversity, Ecosystem, Spiders, India.

Introduction

Spiders are arthropods that belong to the order Araneae, which constitutes the seventh largest in the living world. India is home to 63 of the 139 known spider families and 1,990 of the 53,783 spider species recorded worldwide (World Spider Catalog, 2026; Caleb & Sankaran, 2026). Spiders can adapt to different ecosystems, making them one of the most diverse orders of invertebrates after some insect groups. They can adapt to both the physical and biotic factors. The community of spiders in an ecosystem can vary according to the flora and some critical factors, including salinity and water retention capacity of the soil and the insect prey species present.

Spiders are generalist predator species. They are useful in agriculture since they help in controlling pest insect and mite populations in fruit, vegetable and field crops (Symondson *et al.*, 2002). Spiders have several qualities due to their distinctive response to the natural, anthropogenic activities, easy identification and availability; they can be studied to be used as a good biological indicator for monitoring the health of the ecosystem (Jung *et al.*, 2005).

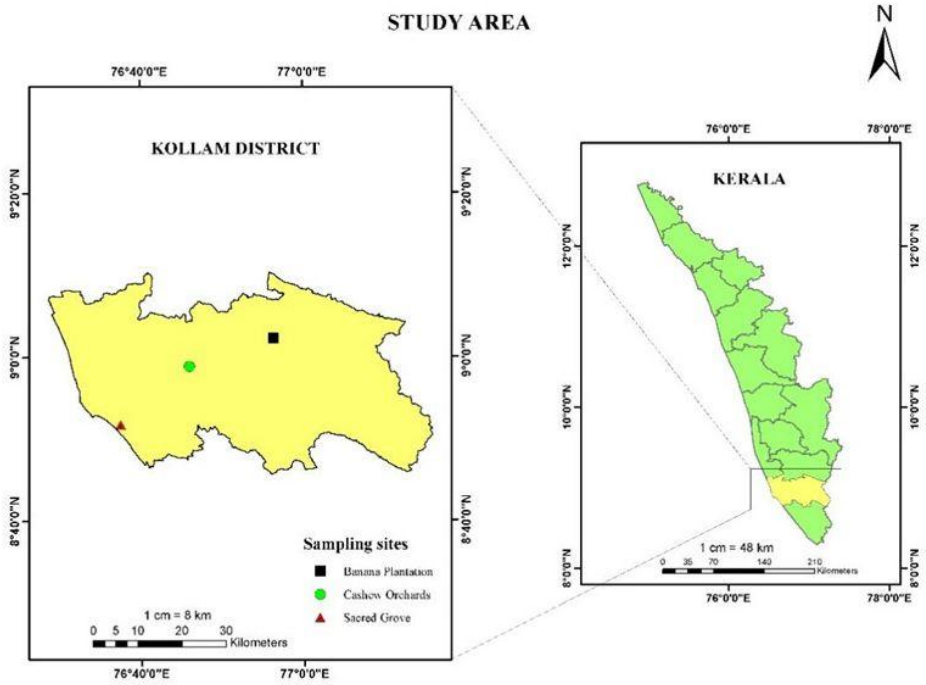

Fig. 1. Sampling sites in Kollam district, Kerala.

In Kerala, a mosaic of traditional and agricultural landscapes offers unique opportunities to examine how different ecosystems support spider assemblages. Sacred groves are chips of forests with heterogeneous size, vegetation, and edaphic factors, protected by a particular community that revives on ancient tradition. India is home to a vast number of sacred groves, with approximately 13,720 sacred groves spread across 19 states (Kapoor, 2006). Among these, the state of Kerala is particularly notable, containing between 1,500 and 2,000 sacred groves. The size of these groves varies significantly, ranging from as small as 0.004 hectares to more than 20 hectares. A study in the sacred groves of northern Kerala recorded 257 species (Sumesh & Sudhikumar, 2021) due to their structural complexity and minimal disturbance.

In contrast, banana plantations are characterised by simplified vegetation structure, frequent management interventions, and high levels of anthropogenic

disturbance, factors known to reduce arthropod diversity (Perfecto & Vandermeer, 2008). In the cashew ecosystem, pest management primarily relies on synthetic insecticides. A study on spider fauna in the cashew orchards recorded 63 spider species from the area (Smitha & Sudhikumar, 2020). The present study aims to assess and compare spider species richness, abundance, and community structure in these three contrasting ecosystems.

Methodology

The study areas were located in 3 different ecosystems in the Kollam district, Kerala (Fig. 1). The study was conducted from March 2024 to February 2025. Habitats which likely to support the existence of spiders were carefully searched. Whole area made in to several transects of 25 metres length and 2.5 metres width to each side in regular intervals of 5 metres. Most of the specimens were collected by the hand-picking method and preserved in 70% ethanol and were studied, photographed by using a Leica M205C stereomicroscope, a Leica DFC450 Camera, and LAS software (Ver.4.13). Adult specimens were identified using available literature (Barrion & Litsinger, 1995; Sebastian & Peter, 2009; World Spider Catalog, 2026). The identified species of spiders were categorized under different guilds (Cardoso *et al.*, 2011).

Alpha diversity

Alpha diversity indices were computed using the *vegan* package in R (Oksanen *et al.*, 2022). Species richness was determined as the total number of species recorded per habitat. The Shannon index and Simpson index were used to assess species diversity, accounting for both richness and relative abundance. Evenness was calculated to evaluate the uniformity of species distribution within each habitat. These metrics provided complementary insights into community structure, dominance patterns, and ecological balance across the surveyed habitats.

Beta diversity

Beta diversity analysis was carried out by Sørensen and Bray-Curtis indices. Beta diversity was quantified to assess compositional dissimilarity among ant communities across three distinct habitats: Sacred grove, Banana plantation, and Cashew orchards. Two complementary indices were employed: the Sørensen index, which captures species turnover based on presence-absence data, and the Bray-Curtis index, which incorporates species abundance to reflect both turnover and nestedness. To assess beta diversity across habitats, species-by-site abundance data were structured into a matrix with species as rows and habitats as columns. Sørensen similarity was computed based on presence-absence data, capturing species turnover irrespective of abundance. Bray-Curtis similarity was derived from raw abundance values, incorporating both species composition and relative abundance to reflect nestedness and turnover. In both cases, pairwise dissimilarity values were calculated and subsequently transformed into similarity scores to facilitate ecological interpretation. All analyses were conducted using the *vegan* package in R (Oksanen *et al.*, 2022), and results were visualized as heatmaps using the *heatmap* package (Kolde, 2019), enabling intuitive comparison of community overlap among Sacred grove, Banana plantation, and Cashew orchards.

Indicator species analysis

Indicator species analysis was conducted to detect species with statistically significant associations to one or more habitats-Sacred grove, Banana plantation and Cashew orchards. The analysis was based on a species by site abundance matrix,

transposed to align species as columns and sites as rows. Habitat labels were assigned to each site and the IndVal.g method was applied using the multipatt() function from the indicspecies R package (De Caceres & Legendre, 2009). Statistical significance was assessed through 999 permutations at an alpha level of 0.05.

Results

A total of 96 species of 19 families and 71 genera were recorded in the three study ecosystems (Table 1). Sacred groves exhibited the highest spider richness (92 species), followed by cashew orchards (62 species) and banana ecosystems (51 species).

Table 1. Checklist of spiders collected from the study area.

Species	
I. Araneidae	**XIII. Salticidae**
1. *Anepsion maritatum* (O. Pickard-Cambridge, 1877)	48. *Asemonea tenuipes* (O. Pickard-Cambridge, 1869)
2. *Arachnura angura* Tikader, 1970	49. *Bianor angulosus* (Karsch, 1879)
3. *Argiope aemula* (Walckenaer, 1841)	50. *Brettus adonis* Simon, 1900
4. *Argiope anasuja* Thorell, 1887	51. *Brettus cingulatus* Thorell, 1895
5. *Argiope pulchella* Thorell, 1881	52. *Carrhotus viduus* (C.L. Koch, 1846)
6. *Chorizopes quadrituberculata* Roy, Sen, Saha & Raychaudhuri, 2014	53. *Chalcotropis pennata* Simon, 1902
7. *Cyclosa hexatuberculata* Tikader, 1982	54. *Curubis tetrica* Simon, 1902
8. *Cyclosa quinqueguttata* (Thorell, 1881)	55. *Epeus alboguttatus* (Thorell, 1887)
9. *Cyrtophora cicatrosa* (Stoliczka, 1869)	56. *Epeus albus* Prószynski, 1992
10. *Cyrtophora citricola* (Forskål, 1775)	57. *Hasarius adansoni* (Audouin, 1825)
11. *Cyrtophora unicolor* (Doleschall, 1857)	58. *Hyllus semicupreus* (Simon, 1885)
12. *Eriovixia laglaizei* (Simon, 1877)	59. *Indopadilla insularis* (Malamel, Sankaran & Sebastian, 2015)
13. *Eriovixia poonaensis* (Tikader & Bal, 1981)	60. *Phintella vittata* (C.L. Koch, 1846)
14. *Gasteracantha geminata* (Fabricius, 1798)	61. *Plexippus minor* Wesołowska & van Harten, 2010
15. *Leviaraneus viridiventris* (Yaginuma, 1969)	62. *Plexippus paykulli* (Audouin, 1825)
16. *Neoscona bengalensis* Tikader & Bal, 1981	63. *Plexippus petersi* (Karsch, 1878)
17. *Neoscona elliptica* Tikader & Bal, 1981	64. *Portia* sp.
18. *Neoscona nautica* (L. Koch, 1875)	65. *Rhene flavigera* (C.L. Koch, 1846)
19. *Porcataraneus bengalensis* (Tikader, 1975)	66. *Siler semiglaucus* (Simon, 1901)
20. *Thelacantha brevispina* (Doleschall, 1857)	67. *Stenaelurillus indicus* Logunov, 2020
II. Cheiracanthiidae	68. *Stenaelurillus lesserti* Reimoser, 1934
21. *Cheiracanthium melanostoma* (Thorell, 1895)	69. *Telamonia dimidiata* (Simon, 1899)
22. *Cheiracanthium poonaense* Majumder & Tikader, 1991	70. *Thiania bhamoensis* Thorell, 1887
III. Clubionidae	**XIV. Scytodidae**
23. *Clubiona drassodes* O. Pickard-Cambridge, 1874	71. *Scytodes thoracica* (Latreille, 1802)
IV. Corinnidae	**XV. Sicariidae**
24. *Castianeira furva* Sankaran, Malamel, Joseph & Sebastian, 2015	72. *Loxosceles* sp.
25. *Castianeira zetes* Simon, 1897	**XVI. Tetragnathidae**
26. *Castianeria* sp.	73. *Leucauge fastigata* (Simon, 1877)
27. *Corinnomma severum* (Thorell, 1877)	74. *Leucauge tessellata* (Thorell, 1887)
V. Dictynidae	75. *Tetragnatha cochinensis* Gravely, 1921
28. *Anaxibia* sp.	76. *Tetragnatha hasselti* Thorell, 1890
VI. Gnaphosidae	77. *Tetragnatha keyserlingi* Simon, 1890
29. *Drassodes* sp.	78. *Tetragnatha mandibulata* Walckenaer, 1841
	79. *Tylorida ventralis* (Thorell, 1887)

30. *Zelotes jabalpurensis* Tikader & Gajbe, 1976

VII. Hersiliidae

31. *Hersilia savignyi* Lucas, 1836
32. *Hersilia striata* Wang & Yin, 1985

VIII. Liocranidae

33. *Sphingius bilineatus* Simon, 1906

IX. Lycosidae

34. *Hippasa agelenoides* (Simon, 1884)
35. *Lycosa tista* Tikader, 1970
36. *Pardosa sumatrana* (Thorell, 1890)
37. *Wadicosa ghatica* Kronestedt, 2017

X. Oxyopidae

38. *Hamadruas hieroglyphica* (Thorell, 1887)
39. *Hamataliwa* sp.
40. *Oxyopes birmanicus* Thorell, 1887
41. *Oxyopes hindostanicus* Pocock, 1901
42. *Oxyopes javanus* Thorell, 1887
42. *Oxyopes shweta* Tikader, 1970
43. *Peucetia viridana* (Stoliczka, 1869)

XI. Pholcidae

44. *Crossopriza lyoni* (Blackwall, 1867)
45. *Pholcus phalangioides* (Fuesslin, 1775)

XII. Pisauridae

46. *Dendrolycosa gitae* (Tikader, 1970)
47. *Pisaura* sp.

XVII. Theridiidae

80. *Achaearanea durgae* Tikader, 1970
81. *Argyrodes argentatus* O. Pickard-Cambridge, 1880
82. *Chikunia nigra* (O. Pickard-Cambridge, 1880)
83. *Famakytta flavescens* (O. Pickard-Cambridge, 1880)
84. *Famakytta miniacea* (Doleschall, 1857)
85. *Meotipa* sp.
86. *Nesticodes rufipes* (Lucas, 1846)
87. *Parasteatoda tepidariorum* (C.L. Koch, 1841)
88. *Physcoa angula* (Tikader, 1970)
89. *Propostira quadrangulata* Simon, 1894
90. *Steatoda* sp.

XVIII. Thomisidae

91. *Amyciaea forticeps* (O. Pickard-Cambridge, 1873)
92. *Camaricus formosus* Thorell, 1887
93. *Thomisus andamanensis* Tikader, 1980
94. *Thomisus lobosus* Tikader, 1965

XIX. Uloboridae

95. *Philoponella rostralis* Shilpa & Sudhikumar, 2022
96. *Uloborus jabalpurensis* Bhandari & Gajbe, 2001

The comparative analysis of biodiversity indices across the three studied ecosystems, Sacred grove, Cashew orchards, and Banana plantation, revealed marked differences in species richness and diversity. Species richness was highest in the Sacred Grove (92 species), followed by Cashew orchards (62 species) and Banana plantation (51 species). This indicates that the Sacred grove supports a substantially larger pool of species compared to the cultivated systems. Shannon index further highlight this trend, with the Sacred grove recording the highest diversity (4.371), while both Cashew orchards and Banana plantation showed comparatively lower but equal values (3.745). Simpson index were consistently high across all sites, suggesting dominance was low and species were well distributed. The Sacred grove (0.986) exhibited slightly greater diversity than Cashew orchards (0.973) and Banana plantation (0.973). Evenness values were close to 1 in all ecosystems, indicating a relatively uniform distribution of individuals among species. The Sacred grove (0.967) showed the highest evenness (Table 2).

Table 2. Biodiversity indices of Sacred grove, Cashew orchards, and Banana plantation.

Indices	Sacred grove	Cashew orchards	Banana plantation
Species richness	92	62	51
Shannon index	4.371	3.745	3.745
Simpson index	0.986	0.973	0.973
Evenness	0.967	0.957	0.953

Alpha diversity in Sacred grove

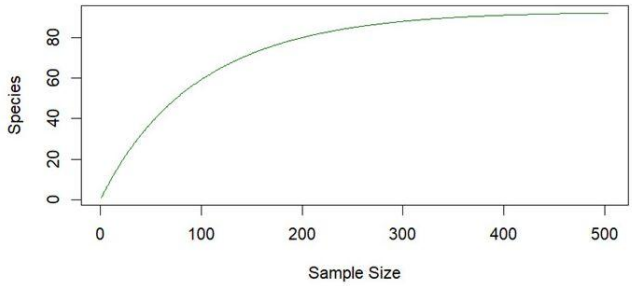

Fig. 2. Species accumulation curve illustrating the relationship between sampling effort and observed species richness in Sacred groves.

The species accumulation curve for the sacred grove spider community showed a rapid initial increase in species richness, followed by a gradual plateau, indicating that sampling effort was sufficient to capture the majority of species present (Fig. 2). The asymptotic nature of the curve suggests low likelihood of encountering additional species with further sampling, supporting the robustness of our diversity estimates.

Alpha diversity in Cashew orchards

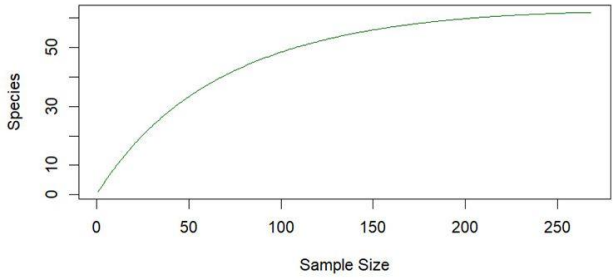

Fig. 3. Species accumulation curve illustrating the relationship between sampling effort and observed species richness in Cashew orchards.

The curve (Fig. 3) shows a rapid initial increase in species count with rising sample size, followed by a gradual plateau, indicating that most species in the community were captured early in the sampling process. This asymptotic trend suggests that the sampling effort was sufficient to represent the habitat's biodiversity, with diminishing returns in new species detection beyond the current sample size.

Alpha diversity in Banana plantation

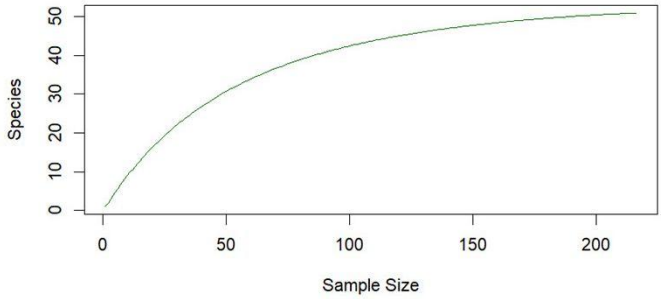

Fig. 4. Species accumulation curve showing the relationship between sampling effort and species richness in the banana habitat.

The curve (Fig. 4) steeply rises at first and gradually levels off, indicating that initial sampling captured many species rapidly, but additional effort yields diminishing returns. This asymptotic pattern suggests that sampling was sufficiently thorough to capture most of the community's diversity, with few new species expected beyond the current sample size.

Beta diversity

Table 3. Bray-Curtis similarity index.

Habitat pair	Similarity score
Sacred grove Vs Cashew orchards	0.594
Sacred grove Vs Banana plantation	0.496
Banana plantation Vs Cashew orchards	0.472

Sacred grove appears to be the most species rich and ecologically diverse, showing stronger similarity with Cashew orchards than with Banana plantation. Banana plantation likely supports fewer or more specialised species, leading to lower similarity with both other habitats. The relatively high similarity between Sacred grove and Cashew orchards may reflect shared microhabitats, structural complexity, or less disturbance compared to the monoculture of bananas.

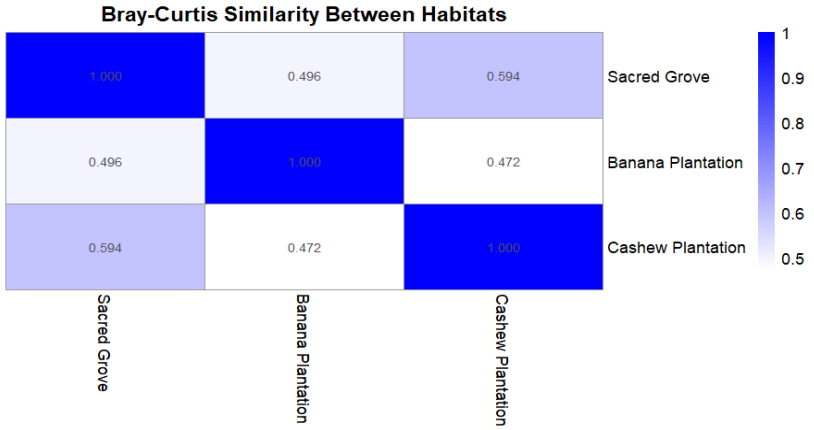

Fig. 5. Bray-Curtis similarity heatmap comparing spider species composition and abundance across three habitats: Sacred grove, Banana plantation, and Cashew orchards. Darker shades indicate higher ecological similarity. Sacred grove and Cashew orchards share the most similar communities (0.594), while Banana plantation is the most distinct (lowest similarity: 0.472).

Table 4. Sorensen similarity index.

Habitat pair	Sørensen similarity
Sacred grove Vs Cashew orchards	0.400
Banana plantation Vs Cashew orchards	0.400
Sacred grove Vs Banana plantation	0.286
Sacred grove Vs Banana plantation (Species row)	0.212
Sacred grove Vs Cashew orchards (Species row)	0.058

Bray-Curtis and Sørensen similarity indices revealed consistent patterns in community overlap across habitats (Fig. 5; Table 4). Sacred grove and Cashew orchards exhibited the highest similarity in both abundance-based (Bray-Curtis: 0.594) and presence/absence-based (Sørensen: 0.400) metrics, indicating shared species and comparable community structure. Banana plantation was the most distinct in Bray-Curtis (0.472), reflecting differences in species abundance, while Sørensen showed moderate overlap with both other habitats (0.286 - 0.400), suggesting the presence of shared but less abundant species.

Indicator species analysis

Indicator species analysis using the IndVal.g function at a significance threshold of alpha = 0.05 yielded. No species were identified as significant indicators for any habitat, suggesting that species distributions across Sacred grove, Banana plantation, and Cashew orchards are either too uniform or too sparse for statistical association. No species met the threshold for significant association, likely due to sparse distributions and limited replication across sites.

Discussion

The present study demonstrates that spider diversity varies across three ecosystems, primarily influenced by differences in habitat complexity, vegetation structure, disturbances and pesticide use. The Sacred grove consistently supported the highest diversity, a pattern typical of undisturbed forest patches, which are known to function as refugiae for a wide range of arthropods (Uetz, 1991; Dias *et al.*, 2010). Sacred groves being less disturbed, dense vegetation, stable microclimatic conditions, and a multi-layered canopy support high diversity.

Cashew orchards are managed agricultural systems. The moderate-to-high species richness (62 species) and substantial Shannon index (3.745) indicate that cashew orchards offer structural heterogeneity due to tree-based cropping, leaf litter accumulation, and reduced ground disturbance compared to banana plantations. The Cashew orchards richness (62 species) aligns with previous studies in cashew ecosystems in Kerala, which also reported substantial spider diversity (Smitha & Sudhikumar, 2020). However, periodic pesticide application and human activity may limit community complexity compared to the Sacred grove.

The Banana plantation exhibited the lowest species richness and diversity indices. Banana monocultures are generally characterised by low structural complexity, frequent disturbances, and reduced ground vegetation, which collectively restrict niche specialisation and habitat availability for spiders (Riechert & Bishop, 1990).

Overall, the comparative analysis highlights that habitat complexity and disturbance level are the major drivers of spider community structure, with the Sacred grove serving as a biodiversity reservoir, while agroecosystems, especially monoculture plantations, support comparatively fewer species.

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Contributions to *Arabelia pheidoleicomes* Bosselaers, 2009 (Araneae: Liocranidae) in Türkiye

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Abstract

Arabelia pheidoleicomes Bosselaers, 2009 is known from the Central Anatolia and Inner Western Anatolia in Türkiye. In this study, we collect this species from new locality in Mediterranean region of Türkiye. General habitus and genitalia of both sexes are illustrated.

Keywords: Araneae, *Arabelia pheidoleicomes*, new locality, Anatolia.

Introduction

The spider family Liocranidae Simon, 1897 contains 35 genera and 358 species all over the world, including 10 genera and 24 species reported in Türkiye. The spider genus *Arabelia* was established by Bosselaers in 2009 based on the female holotype of *Arabelia pheidoleicomes* from Greece. It is represented by only two species: *Arabelia pheidoleicomes* Bosselaers, 2009 from Greece, Cyprus, Türkiye and *Arabelia xizang* Mu & Zhang, 2022 from China (Demir & Seyyar, 2017; Danışman *et al.*, 2025; World Spider Catalog, 2026). It was assigned to the family Liocranidae due to several morphological characteristics, including a flattened carapace, a narrow eye field, the absence of abdominal sclerotisation, and the presence of an anterior epigynal hood (Bosselaers, 2009). Bosmans (2011) described the male of *A. pheidoleicomes* from Greece too.

In Türkiye, this species was previously recorded only from female specimens from Aksaray province (Seyyar *et al.*, 2016) and Afyonkarahisar province (Seyyar *et al.* (2018) (Fig. 1).

In this study, we could find male specimens of this species for the first time and added new data on the distribution in Türkiye and expands the distribution area of the species.

Material and Methods

In this study, one male and two female specimens were collected from Mersin province (Mediterranean region) in southern of Anatolia. Examined specimens were preserved in 70% ethanol and deposited in the Arachnology Museum of Niğde Ömer Halisdemir University (NÖHUAM). For identification, Seyyar *et al.* (2016), Bosmans (2011), and Bosselaers (2009) were consulted. The identification was made by means of a SZX61 Olympus stereomicroscope.

Fig 1. Localities of genus *Arabelia* and *A. pheidoleicomes* Bosselaers, 2009 in Türkiye.

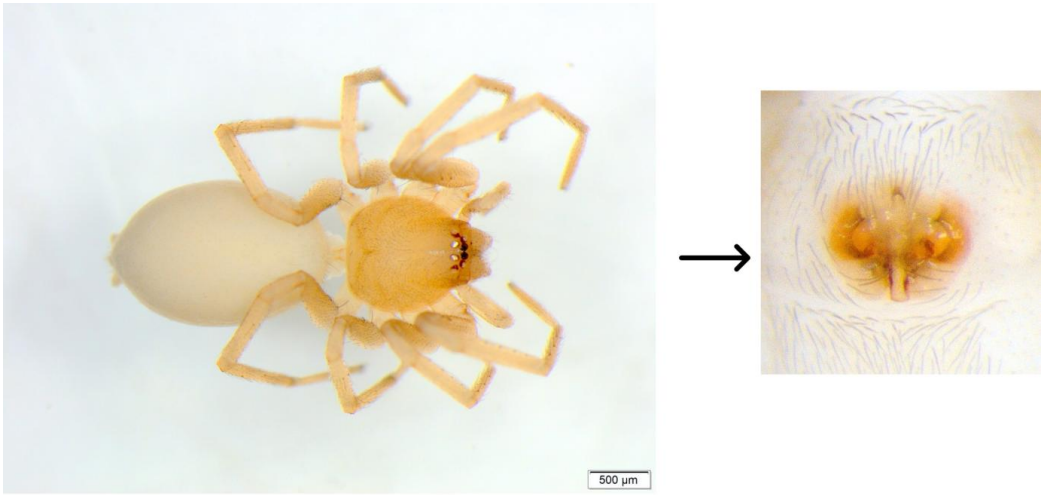

Fig. 2. *Arabelia pheidoleicomes* Bosselaers, 2009. A. Female habitus. B. Epigyne.

Results

Arabelia pheidoleicomes Bosselaers, 2009 Figs. (2-3)

Examined specimens: 1♂,1♀ Türkiye: Mersin Province, Bozyazı district, nearly 945 m, 07.III.2025, Leg. Osman Seyyar, found under stones.

Description: Female (Fig. 2): A. habitus, dorsal view. B. Epigyne, ventral view. Male (Fig. 3): A. habitus, dorsal view. B-D. Male palp. B. prolateral view. C. ventral view. D. retrolateral view. Also, see Bosselaers (2009) for female and Bosmans (2011) for male.

Distribution: Greece, Cyprus, Türkiye (World Spider Catalog, 2026).

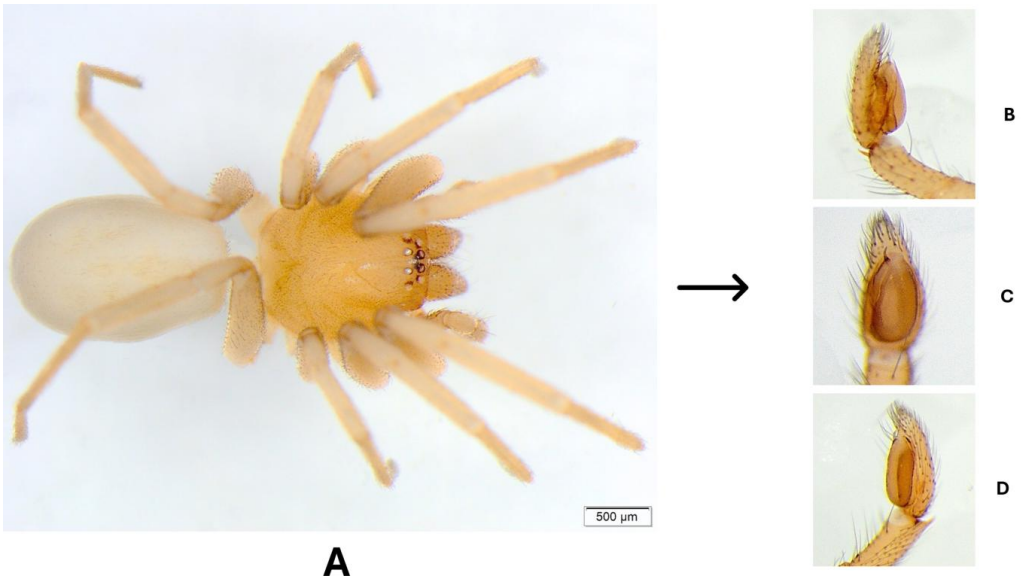

Fig. 3. *Arabelia pheidoleicomes* Bosselaers, 2009. A. Male habitus. B-D. Male palp. B. prolateral view. C. ventral view. D. retrolateral view.

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New data on *Ozyptila kahramanmarasensis* Coşar & Danışman, 2021 (Araneae: Thomisidae) in Türkiye

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Abstract

Ozyptila kahramanmarasensis Coşar & Danışman, 2021 is known from the Eastern Mediterranean Region in Türkiye. In this study, we collected this species from a new locality in Mediterranean region of Türkiye. General habitus and genitalia of male specimen are illustrated.

Keywords: Araneae, *Ozyptila kahramanmarasensis*, new locality, Anatolia.

Introduction

The spider family Thomisidae Sundevall, 1833 contains 172 genera and 2197 species all over the world, including 16 genera and 93 species reported in Türkiye. *Ozyptila* Simon, 1864 is one of the largest genera of this family. It is represented by 106 species in the world and 16 species in Türkiye (World Spider Catalog, 2026; Danışman *et al.*, 2025a; Demir & Seyyar, 2017).

In Türkiye, *Ozyptila kahramanmarasensis* Coşar & Danışman, 2021 species was previously recorded only from male specimens from Kahramanmaraş province (Çoşar & Danışman, 2021) (Fig. 1). In this study, we found a male specimen of this species from Meydan Plateau in Aladağ district. This is a new data on the distribution in Türkiye and it expands the distribution area of the species.

Material and Methods

In this study, one male specimen was collected from Meydan Plateau, Aladağ district in Adana province (Mediterranean region) in southern part of Anatolia. Examined specimen was preserved in 70% ethanol and deposited in the Arachnology Museum of Niğde Ömer Halisdemir University (NÖHUAM). For identification, Çoşar & Danışman (2021) was consulted. The identification was made by means of a SZX61 Olympus stereomicroscope.

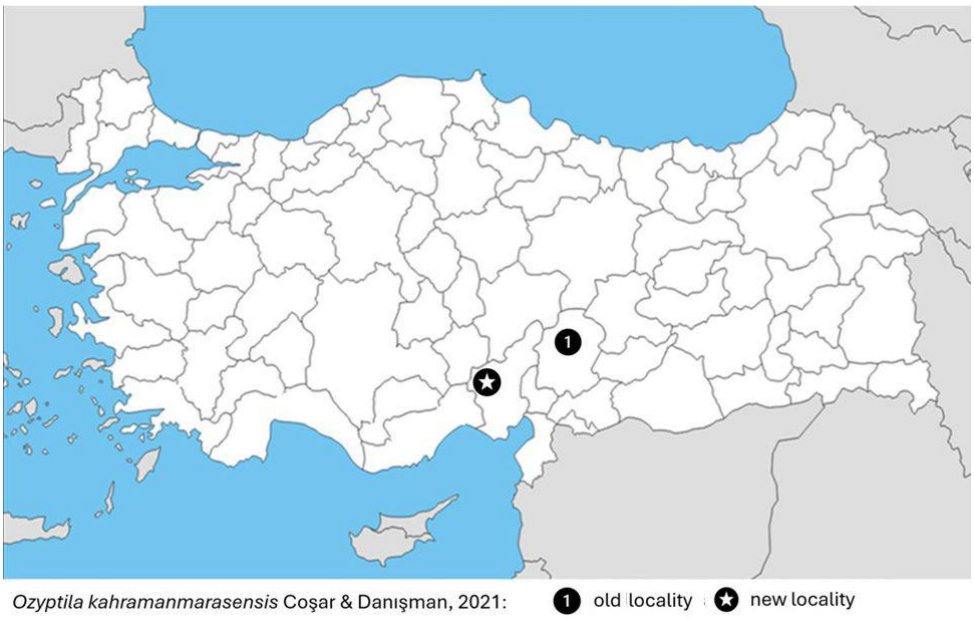

Fig 1. Localities of *Ozyptila kahramanmarasensis* Coşar & Danışman, 2021 in Türkiye.

Results

To date, 16 species of *Ozyptila* have been identified in Türkiye (Table 1) (Demir & Seyyar, 2017; Danışman *et al.*, 2025a, Danışman *et al.*, 2025b; Danışman *et al.*, 2026).

Table 1. The list of *Ozyptila* species in Türkiye.

No.	Species	Reference
1	*Ozyptila ankarensis* Karol, 1966	a
2	*Ozyptila atomaria* (Panzer, 1800)	a
3	*Ozyptila baraki* Danışman, Ayhan & Coşar, 2026	c
4	*Ozyptila claveata* (Walckenaer, 1837)	a
5	*Ozyptila clavidorsum* Roewer, 1959	a
6	*Ozyptila confluens* (C.L. Koch, 1845)	a
7	*Ozyptila conostyla* Hippa, Koponen & Oksola, 1986	a
8	*Ozyptila izmirica* Danışman, Yağmur, Coşar, Kunt & Karakuş, 2025	b
9	*Ozyptila kahramanmarasensis* Coşar & Danışman, 2021	a

10	*Ozyptila praticola* (C.L. Koch, 1837)	a
11	*Ozyptila rauda* Simon, 1875	a
12	*Ozyptila rigida* (O. Pickard-Cambridge, 1872)	a
13	*Ozyptila sanctuaria* (O. Pickard-Cambridge, 1871)	a
14	*Ozyptila simplex* (O. Pickard-Cambridge, 1862)	a
15	*Ozyptila spirembola* Wunderlich, 1995	a
16	*Ozyptila tricoloripes* Strand, 1913	a

a = Danışman *et al.* (2025a), b = Danışman *et al.* (2025b), c = Danışman *et al.* (2026).

Ozyptila kahramanmarasensis Coşar & Danışman, 2021 (Fig. 2)

Examined specimen: 1♂, Türkiye: Adana Province, Meydan-Aladağ (37°30'54"N, 35°23'05"E) nearly 1088 m a.s.l., 04.V.2018, Leg. Hakan Demir. It was found under a stone.

Distribution: Türkiye (World Spider Catalog, 2026).

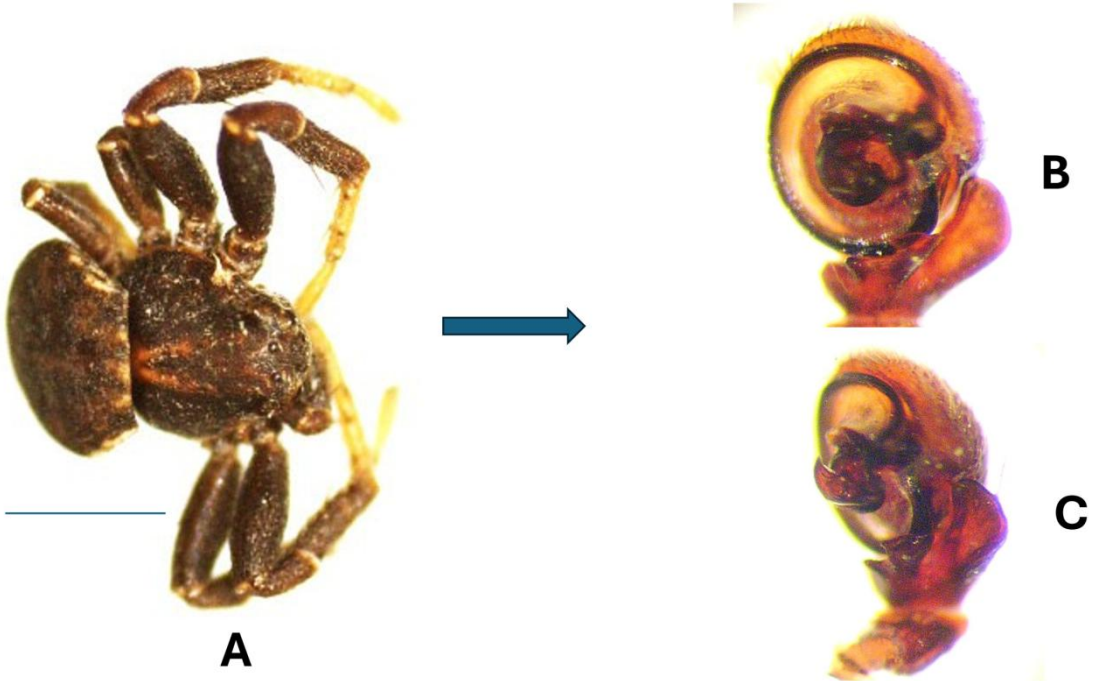

Fig. 2. *Ozyptila kahramanmarasensis* Coşar & Danışman, 2021, male. A. habitus, dorsal view. B-C. palp. B. ventral view. C. retrolateral view. (Scale bar: 2 mm).

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An araneological study on Itulumaz Mountain (Niğde, Türkiye)

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Abstract

Spider specimens were collected by using aspirator, sweep net, and pitfall traps from Itulumaz Mountain located in the province of Niğde in the Central Anatolia between 2023-2025. A total of 47 species belonging to 16 families were studied. All identified species are new records for the study area. All specimens were labelled and preserved as museum material in Arachnology Museum of Niğde Ömer Halisdemir University.

Keywords: Spider, Fauna, Itulumaz Mountain, Türkiye.

Introduction

In the recent years, arenological studies in Türkiye are increasing. Despite this increase, there are still many regions of the country that remain insufficiently investigated. Up to now, 53852 species of 4510 genera in 138 families of spiders have been described in the world (World Spider Catalog, 2026). There are only 1322 species of 374 genera belonging to 58 families known from Türkiye (Demir & Seyyar, 2017; Danışman *et al.*, 2025). The aim of this study is to determine the areneofauna of Itulumaz Mountain (Niğde) of Türkiye.

Material and Methods

All specimens were collected from Itulumaz Mountain in Central Anatolia (Fig. 1) by using aspirator, sweep net, and pitfall traps from three localities at different altitudes in study area during two years, between the 2023-2025 years (Table 1). Samples were made from every side of the mountain (Fig. 2). The identification was made by means of a SZX61 Olympus stereomicroscope. Museum specimens were used for the species identification. The studied specimens were labelled and preserved as museum material in Arachnology Museum of Niğde Ömer Halisdemir University (NOHUAM).

Fig. 1. General view of Itulumaz Mountain (Niğde) and localities (marked in blue).

Table 1. Localities data.

Locality No.	Altitude	Habitat Type
Locality 1	1200-1450 m	General steppe
Locality 2	1450-1700 m	Woodland area
Locality 3	over 1700 m	High-altitude steppe

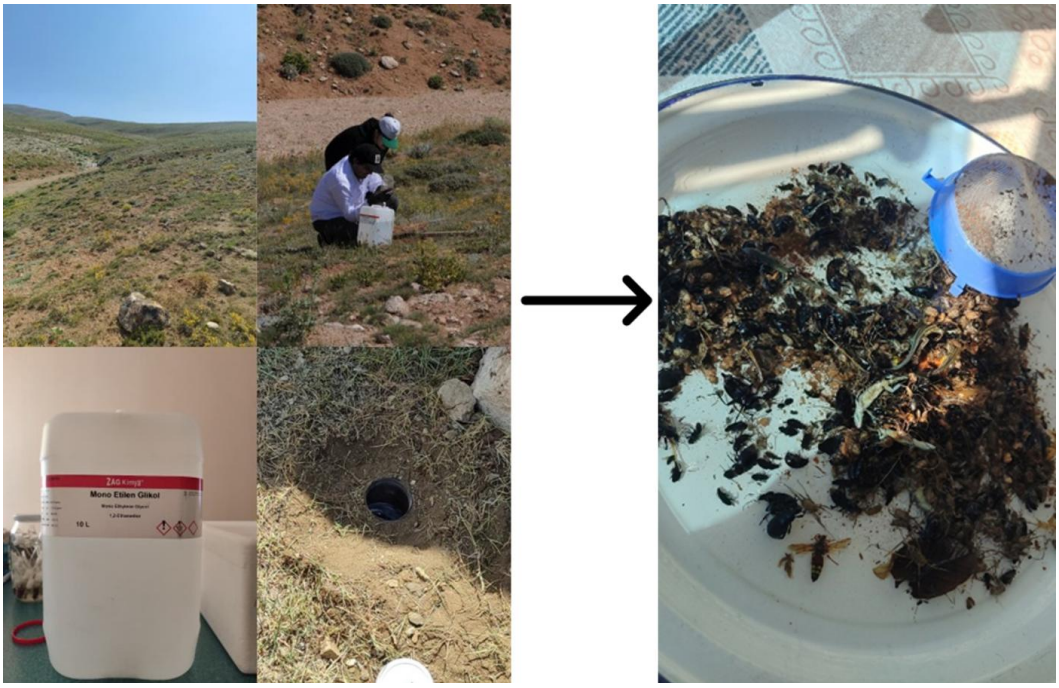

Fig. 2. Photos of fieldworks on the study area.

Results and Discussion

A total of 47 spider species in 16 families determined from the study area. Most species rich families were Gnaphosidae (16), Theridiidae (8), and Lycosidae (5). This considerable taxonomic diversity suggests that the heterogeneous ecological conditions and the wide range of available microhabitats on the mountain play a significant role in shaping species richness. These findings highlight the ecological importance of Mount İtulumaz as a reservoir of arachnid biodiversity and emphasize its value for future faunistic and conservation-oriented studies.

Table 2. The spider list of the study area.

Spider species	♂	♀
Agelenidae C.L. Koch, 1837		
Agelena labyrinthica (Clerck, 1757)	0	3
Maimuna vestita (C.L. Koch, 1841)	1	0
Tegenaria argaeica Nosek, 1905	1	0
Dictynidae O. Pickard-Cambridge, 1871		
Brigittea latens (Fabricius, 1775)	0	2
Dysderidae C.L. Koch, 1837		
Dysdera crocata C.L. Koch, 1838	2	0
Eresidae C.L. Koch, 1845		
Eresus kollari Rossi, 1846	1	0
Eresus lavrosii Mcheidze, 1997	1	0
Gnaphosidae Banks, 1892		
Anagraphis pallens Simon, 1893	1	0
Callilepis cretica (Roewer, 1928)	1	0
Callilepis nocturna (Linnaeus, 1758)	2	2
Civizelotes caucasius (L. Koch, 1866)	2	6
Drassodes lapidosus (Walckenaer, 1802)	1	0
Drassyllus crimeaensis Kovblyuk, 2003	0	1
Drassyllus villicus (Thorell, 1875)	1	0
Haplodrassus dalmatensis (L. Koch, 1866)	0	1
Haplodrassus signifer (C.L. Koch, 1839)	1	0
Marinarozelotes barbatus (L. Koch, 1866)	0	1
Marinarozelotes malkini (Platnick & Murphy, 1984)	1	0
Micaria atropatene Zamani & Marusik, 2021	1	0
Nomisia ripariensis (O. Pickard-Cambridge, 1872)	2	2
Pterotricha lentiginosa (C.L. Koch, 1837)	1	0
Linyphiidae Blackwall, 1859		
Lepthyphantes leprosus (Ohlert, 1865)	0	1
Lycosidae Sundevall, 1833		
Alopecosa pulverulenta (Clerck, 1757)	1	0
Alopecosa striatipes (C.L. Koch, 1837)	0	1

Arctosa tbilisiensis Mcheidze, 1946	0	1
Geolycosa vultuosa (C.L. Koch, 1838)	0	1
Pardosa bifasciata (C.L. Koch, 1834)	0	2
Palpimanidae Thorell, 1869		
Palpimanus orientalis Kulczyński, 1909	1	1
Philodromidae Thorell, 1869		
Thanatus atratus Simon, 1875	1	0
Thanatus pictus L. Koch, 1881	1	0
Pisauridae Simon, 1890		
Pisaura mirabilis (Clerck, 1757)	1	0
Salticidae Blackwall, 1841		
Philaeus chrysops (Poda, 1761)	1	0
Scytodidae Blackwall, 1852		
Scytodes thoracica (Latreille, 1802)	1	0
Theridiidae Sundevall, 1833		
Anatolidion gentile (Simon, 1881)	2	0
Asagena phalerata (Panzer, 1800)	0	1
Enoplognatha mordax (Thorell, 1875)	1	0
Neottiura herbigrada (Simon, 1873)	0	1
Steatoda albomaculata (De Geer, 1778)	0	1
Steatoda triangulosa (Walckenaer, 1802)	0	1
Theridion cinereum Thorell, 1875	1	0
Theridion melanurum Hahn, 1831	0	1
Thomisidae Sundevall, 1833		
Bassaniodes pseudorectilineus (Wunderlich, 1995)	11	2
Bassaniodes tristrami (O. Pickard-Cambridge, 1872)	0	1
Psammitis ninnii	0	1
Xysticus kochi Thorell, 1872	0	4
Titanoecidae Lehtinen, 1967		
Nurscia albomaculata (Lucas, 1846)	1	0
Zodariidae Thorell, 1881		
Zodarion thoni Nosek, 1905	1	0

Acknowledgment

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A study of spider diversity on rubber plantations in Thirumittacode Panchayat, Palakkad District, Kerala, India

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Abstract

The present study was undertaken to investigate the diversity, guild structure, and species abundance of spiders in selected rubber plantations of Thirumittacode, Palakkad. The survey was conducted during the period from September 2025 to January 2026. Spider specimens were collected using various sampling methods, including visual search, inverted umbrella method, bark tapping method, and aerial and ground hand collecting. The collected specimens were preserved in ethyl alcohol and identified up to genus or species level using available taxonomic literature. During the study period, a total of 43 species belonging to 32 genera and 11 families were recorded from the study area. Among the families documented, Salticidae was the most dominant, followed by Araneidae. Analysis of the feeding behaviour of the collected spiders revealed the presence of five distinct feeding guilds. The results indicate that rubber plantation ecosystems support considerable spider diversity and highlight the ecological importance of spiders as natural biological control agents in agricultural landscapes.

Keywords: Spider diversity, Rubber plantations, Ecosystem and Guild structure, India.

Introduction

Phylum Arthropoda is the largest and most diverse group in the animal kingdom, comprising nearly nine hundred thousand species inhabiting aquatic, terrestrial, and parasitic environments. They are characterized by a chitinous exoskeleton and paired, jointed appendages, with Class Insecta representing the majority of species (Ayyar &

Ananthakrishnan, 1994). Arthropods show remarkable adaptability and account for about 80% of known animal species, making them the most successful terrestrial colonizers (Zhang, 2013). They exhibit bilateral symmetry and metameric segmentation, with body units called somites. Sensory organs such as antennae, compound eyes, and statocysts are well developed. Most species are dioecious, showing sexual dimorphism, internal fertilization, and development that may be direct or indirect, often involving larval stages and metamorphosis (Sebastian & Gautam, 2021).

Spiders constitute the second largest order within class Arachnida under the phylum Arthropoda and are distributed across almost all terrestrial ecosystems except Antarctica. As important predatory arthropods, spiders play a crucial ecological role by regulating insect populations and maintaining ecosystem balance. In agricultural habitats such as rubber plantations, spiders contribute significantly to natural pest control, thereby supporting ecological stability. Their varied hunting strategies and sensitivity to environmental changes make them useful indicators of habitat conditions.

Rubber plantations, dominated by *Hevea brasiliensis*, are monoculture systems that still support diverse arthropods due to structural features like leaf litter and vegetation. Spiders occupy various microhabitats and use different foraging strategies, reflecting habitat complexity (Uetz *et al.*, 1999). They act as natural predators, controlling insect pests and aiding sustainable management, and also serve as bioindicators of environmental conditions (Marc *et al.*, 1999; Nyffeler & Birkhofer, 2017; Cardoso *et al.*, 2011).

The present study focuses on assessing the diversity and guild structure of spiders in selected rubber plantation habitats of Thirumittacode Panchayat. Taxonomic studies on spiders in this region are limited, and no comprehensive assessment of spider fauna has been reported so far. Therefore, this study aims to investigate and compare spider diversity across selected habitats, providing baseline data for future research. The findings will also contribute to building a biodiversity database for spider species in the region.

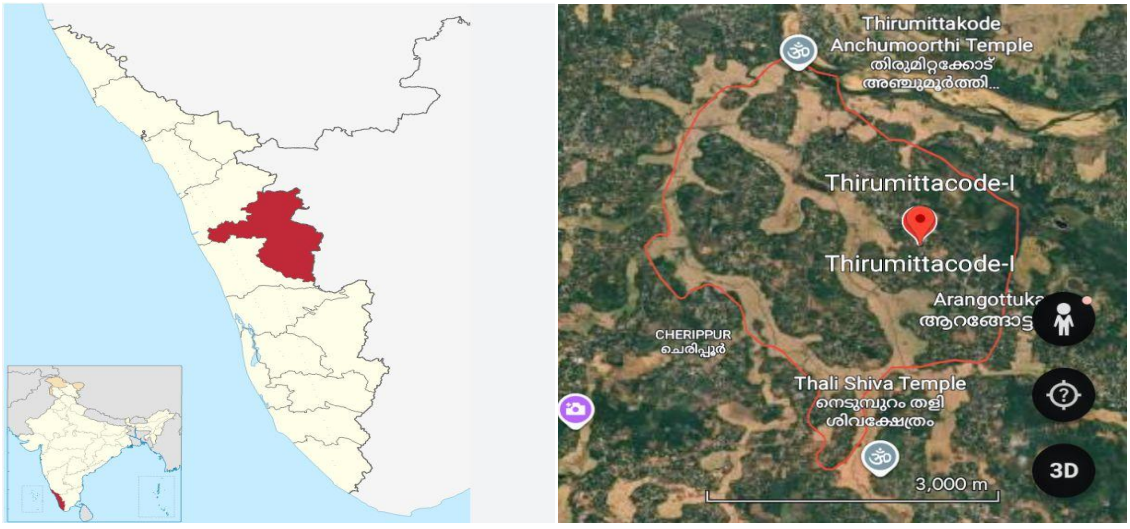

Fig. 1. Map showing the study area.

Material and Methods

The study site selected is a rubber plantation located in Thirumittacode Panchayat, Palakkad (Fig. 1). It lies at 10.765725°N latitude and 76.18787°E longitude, covering an

area of 2 hectares. The average altitude of the plantation is about 40 m above mean sea level. The study area was selected to assess diversity, species richness, abundance, and functional guild composition in the rubber plantation ecosystem. The plantation mainly consists of rubber trees along with small herbs and shrubs. During the study period, a total of 43 species belonging to 32 genera under 11 families were recorded.

The observation and collecting of spiders were carried out over a period of 5 months, from September 2025 to January 2026. A total of 8 samples were collected from the study area during this period. The collections were made in the morning, between 8:00 am and 10:00 am. The line transect method was adopted for sampling spider fauna. Collecting techniques included visual search method, aerial hand collecting, ground hand collecting, inverted umbrella method, and bark tapping method. The collected spiders were preserved separately in bottles containing 80% ethyl alcohol. Identification was carried out up to the genus/species level with the help of available literature (Sebastian & Peter, 2009; World Spider Catalog, 2026; Caleb & Sankaran, 2026).

Diversity indices like Shannon-Wiener index, Simpson's diversity index, Evenness index and Species richness index were calculated using MS Office standard Excel 2013 Programme. The spider guild classification was constructed habitat wise, based on the families collected during the study. Classification of guild in the current study was according to the results of Cardoso *et al.* (2011).

Table 1. Checklist of spiders collected from entire study area.

NO.	Family / Genus / Species	Species Abundance
	1. ARANEIDAE	
1.	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	3
2.	*Argiope pulchella* Thorell, 1881	5
3.	*Cyclosa hexatuberculata* Tikader, 1982	2
4.	*Cyclosa moonduensis* Tikader, 1963	1
5.	*Cyrtophora cicatrosa* (Stoliczka, 1869)	1
6.	*Gasteracantha geminata* (Fabricius, 1798)	1
7.	*Gasteracantha kuhli* C.L. Koch, 1837	2
8.	*Neoscona mukerjei* Tikader, 1980	2
	2. CORINNIDAE	
9.	*Castianeira zetes* Simon, 1897	3
	3. ERESIDAE	
10.	*Stegodyphus sarasinorum* Karsch, 1892	2
	4. HERSILIIDAE	
11.	*Hersilia savignyi* Lucas, 1836	4
	5. LYCOSIDAE	
12.	*Pardosa pseudoannulata* (Bösenberg & Strand, 1906)	2
13.	*Pardosa sumatrana* (Thorell, 1890)	3
	6. OXYOPIDAE	
14.	*Hamadruas sikkimensis* (Tikader, 1970)	5
15.	*Oxyopes hindostanicus Pocock, 1901*	4
16.	*Oxyopes lineatipes* (C.L. Koch, 1847)	3
17.	*Oxyopes shweta* Tikader, 1970	5
	7. PHOLCIDAE	
18.	*Artema atlanta* Walckenaer, 1837	15
19.	*Crossopriza lyoni* (Blackwall, 1867)	3
20.	*Micropholcus fauroti* (Simon, 1887)	5

	8. SALTICIDAE	
21.	*Afraflacilla adavathurensis* Sampathkumar & Caleb, 2023	5
22.	*Epocilla aurantiaca* (Simon, 1885)	4
23.	*Hindumanes karnatakaensis* (Tikader & Biswas, 1978)	15
24.	*Hyllus semicupreus* (Simon, 1885)	11
25.	*Menemerus bivittatus* (Dufour, 1831)	7
26.	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	15
27.	*Plexippus paykulli* (Audouin, 1825)	5
28.	*Plexippus petersi* (Karsch, 1878)	7
29.	*Rhene flavigera* (C.L. Koch, 1846)	4
30.	*Stenaelurillus albus* Sebastian, Sankaran, Malamel & Joseph, 2015	3
31.	*Stenaelurillus lesserti* Reimoser, 1934	5
32.	*Telamonia dimidiata* (Simon, 1899)	10
33.	*Telamonia festiva* Thorell, 1887	5
	9. TETRAGNATHIDAE	
34.	*Tetragnatha viridorufa* Gravely, 1921	3
	10. THERIDIIDAE	
35.	*Argyrodes argentatus* O. Pickard-Cambridge, *1880*	5
36.	*Argyrodes gazedes* Tikader, 1970	4
37.	*Chikunia nigra* (O. Pickard-Cambridge, 1880)	2
38.	*Famakytta flavescens* (O. Pickard-Cambridge, 1880)	6
39.	*Nihonhimea mundula* (L. Koch, 1872)	6
40.	*Parasteatoda celsabdomina* (Zhu, 1998)	2
	11. THOMISIDAE	
41.	*Oxytate virens* (Thorell, 1891)	5
42.	*Thomisus lobosus* Tikader, 1965	2
43.	*Thomisus projectus* Tikader, 1960	3

Table 2. Genera and species in different spider families of the entire spider assemblage recorded in the study area.

FAMILY	Number of Genera	Number of Species
ARANEIDAE	6	8
CORINNIDAE	1	1
ERESIDAE	1	1
HERSILIIDAE	1	1
LYCOSIDAE	1	2
OXYOPIDAE	2	4
PHOLCIDAE	3	3
SALTICIDAE	10	13
TETRAGNATHIDAE	1	1
THERIDIIDAE	4	6
THOMISIDAE	2	3
	32	43

Results

A total of 43 species belonging to 32 genera under 11 families were collected from the study area (Table 1). Among the 11 families recorded, the family Salticidae was the

most dominant, with 13 species belonging to 10 genera. The family Araneidae was the second most dominant, with 8 species belonging to 6 genera (Table 2 & Fig. 2).

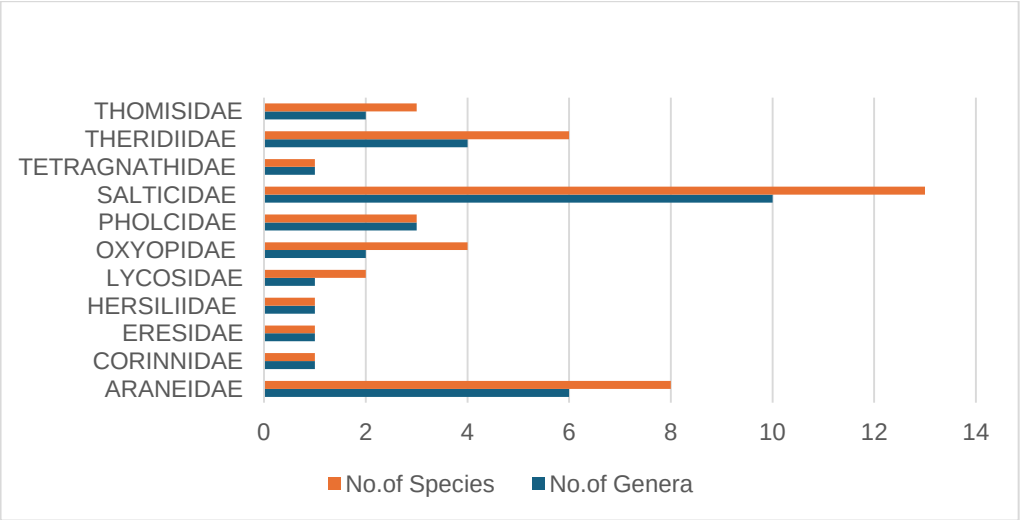

Fig. 2. Graph showing the distribution of genera and species in different spider families of the entire spider assemblage recorded in the study area.

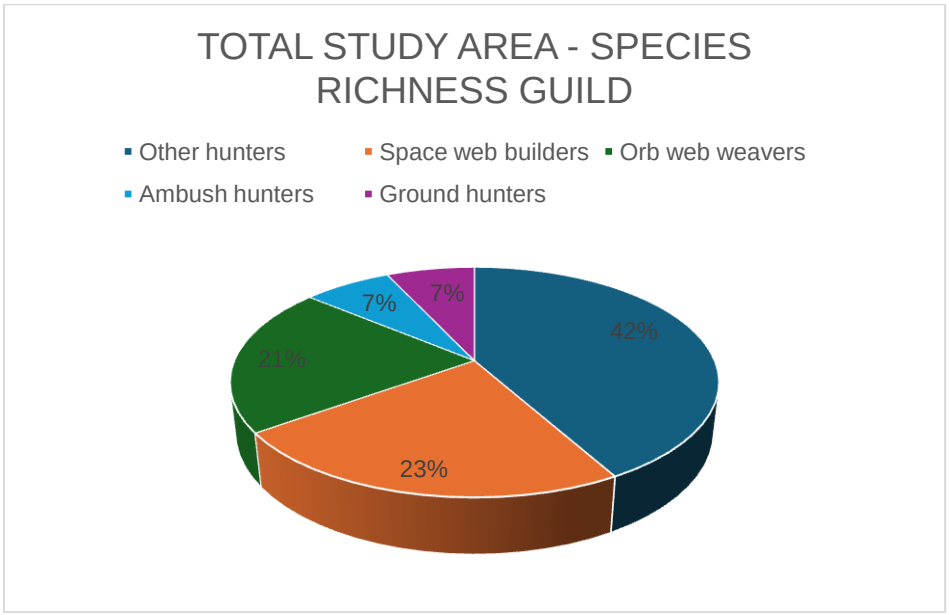

Fig. 3. Species richness of spiders in the guilds of the total study area.

Spiders collected from the selected habitats of the study area were classified into five guilds based on their feeding behaviour, following Pedro Cardoso *et al.* (2011): (1) Ambush hunters (Family Thomisidae); (2) Ground hunters (Corinnidae, Lycosidae); (3) Orb web weavers (Araneidae, Tetragnathidae); (4) Space web builders (Eresidae, Pholcidae, and Theridiidae); and (5) Other hunters (Hersiliidae, Oxyopidae, and Salticidae). The results showed that, among the guilds in the rubber plantation, the "other hunters" guild had the highest species richness, followed by space web builders (Figs. 3 & 4). The most abundant guild was also "other hunters" (57%), followed by space web builders (24%) (Figs. 5 & 6). A diversity index is a single value that reflects both species richness and evenness (Magurran, 1988). In the rubber plantation, the diversity indices

recorded were H′ = 2.034 and SDI = 0.8516. Species richness was approximately 0.2, while evenness was about 0.8 (Table 3).

Table 3. Diversity data on spiders of selected habitat of Thirumittacode Panchayat, Palakkad, Kerala during the study period.

Study area	No. of species (S)	No. of individuals (N)	Species richness (d)	Shannon - Weiner index (H')	Simpson index (D)	Evenness (E)
Total Study area	43	205	0.2558	2.034	0.8516	0.848

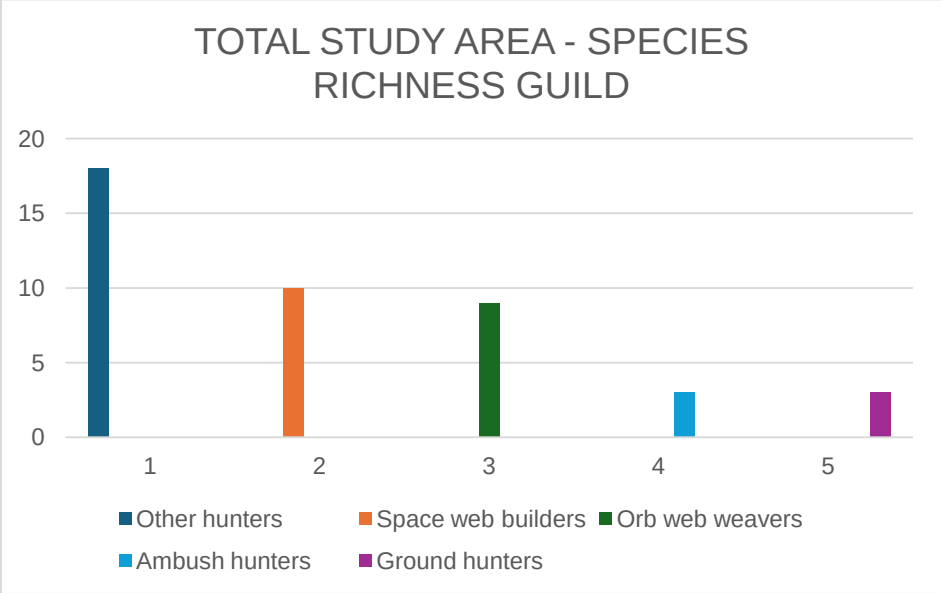

Fig. 4. Species richness of spider in the guilds of the total study area.

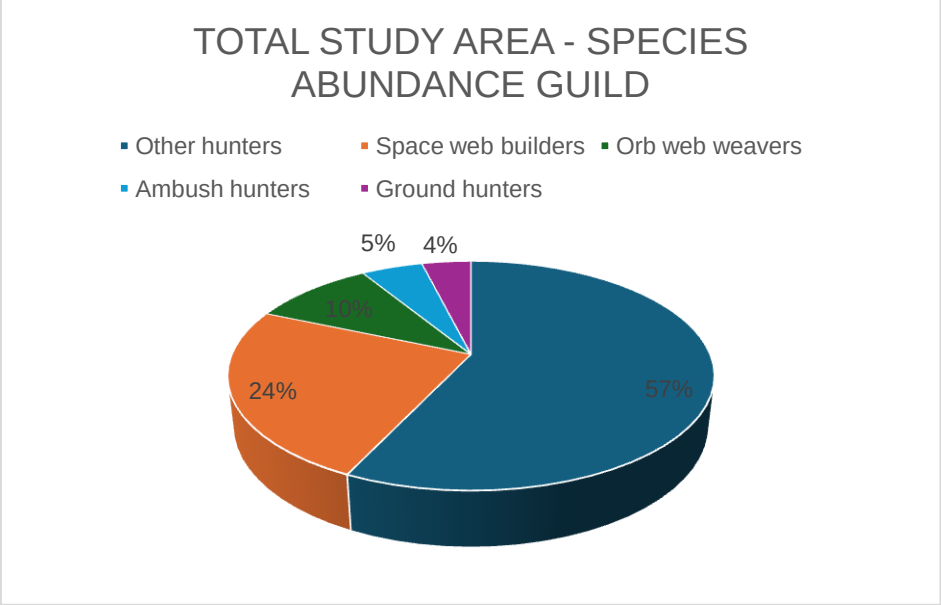

Fig. 5. Species abundance of spiders in the guilds of the study area.

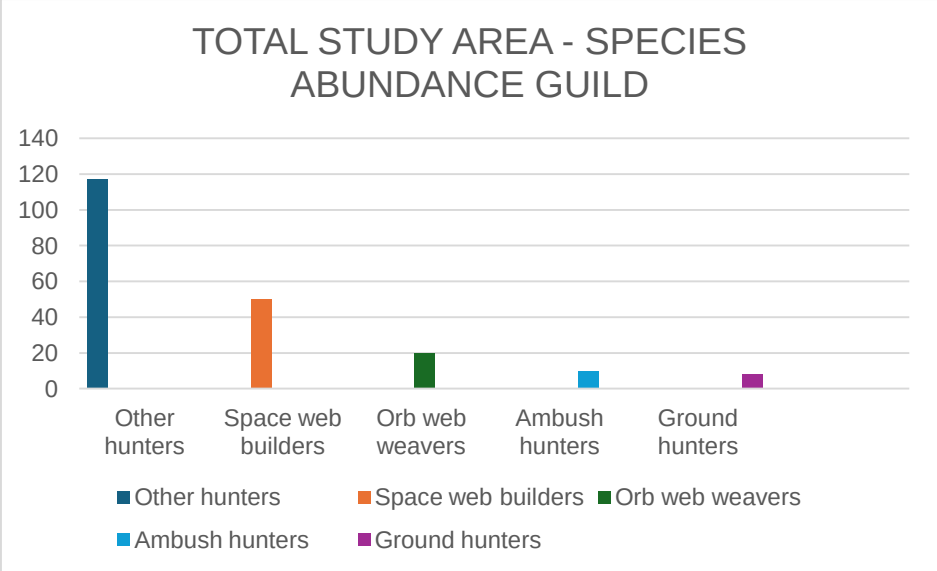

Fig. 6. Species abundance of spider in the guilds of the study area.

Discussion

The present study provides the first documentation of spider fauna in the rubber plantation of Thirumittacode Panchayat, Palakkad. Spiders are adaptable predators whose diversity and abundance are strongly affected by differences in plant community structure, with greater diversity usually found in more heterogeneous habitats. The rubber plantation habitat recorded 43 species belonging to 32 genera under 11 families. The highest species richness and abundance in the study area were observed in the guild of other hunters, followed by space web builders (Figs. 3 & 5). The results indicate a well-defined guild structure, along with notable patterns of relative abundance and species richness in the rubber plantation. This may be attributed to favourable weather and climatic conditions. Monitoring spider diversity patterns provides valuable insights into the biodiversity of tropical ecosystems. In the context of the current global biodiversity crisis, spiders can serve as important ecological indicators for rapid biodiversity assessments, highlighting the need for improved taxonomic resources, especially in tropical regions. The study reveals a diverse species composition across selected habitats, emphasizing the influence of vegetation types on spider fauna. It also provides baseline information on spider ecology and their ecological significance and forming a foundation for future studies and supporting conservation efforts based on spider inventories.

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Diversity and abundance of spiders in rice agroecosystems of Thirumittacode, Palakkad, Kerala, India

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Abstract

Present work is an attempt to study the diversity and guild structure of spiders in rice agroecosystems of Thirumittacode, Palakkad during the period of September 2025 to January 2026. Spider samples were gathered using a variety of sampling techniques, including visual search, beating vegetation, litter sampling, and ground and aerial hand collecting. The collected specimens were preserved in ethyl alcohol and identified up to the level of genus or species using the accessible literature. The purpose of this study was to study the spider diversity, guild structure, and species abundance. During the study period, a total of 64 species from 48 genera in 14 families were collected from the total study area. The Salticidae and Thomisidae families were the most dominant of the 14 families studied in the total study area. The analysis of feeding behaviour of collected spiders revealed a total of six feeding guilds.

Keywords: Spider diversity, Agroecosystem, Guild structure, India.

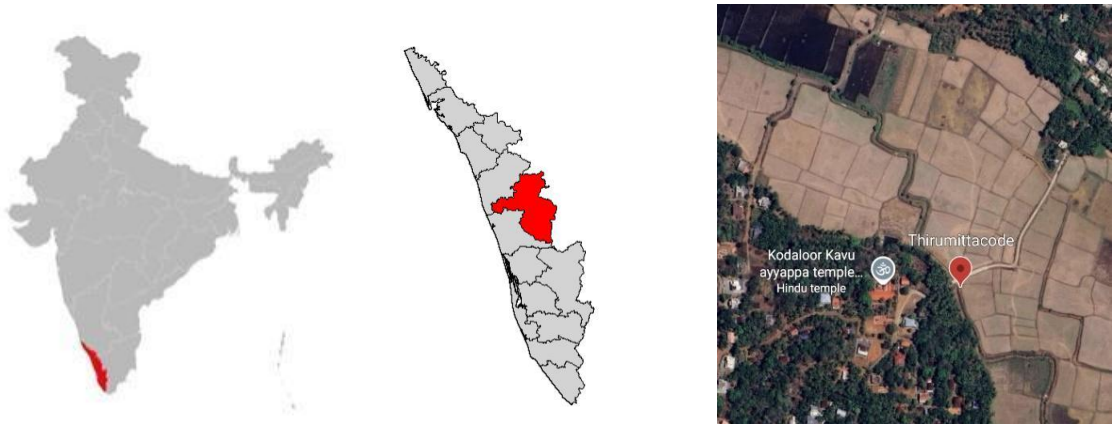
Introduction

Spiders are among the most abundant and diverse predatory arthropods present in agricultural ecosystems. They play a significant role in maintaining ecological balance by regulating insect populations. Due to their sensitivity to environmental changes, spiders

are also considered effective bioindicators of habitat quality and ecosystem health. Spiders exhibit a wide range of foraging strategies and occupy different ecological guilds, which allows them to utilize various niches within an ecosystem. Their presence and diversity therefore provide valuable information about the stability and functioning of agroecosystems.

Agroecosystems are human-managed systems designed for agricultural production, yet they function as complex ecological units with dynamic interactions among biotic and abiotic components. These systems include crops, weeds, soil organisms, arthropods, microorganisms, and higher trophic levels, all influenced by practices such as tillage, irrigation, fertilization, and pest management (Odum, 1971; Altieri, 1999). Compared to natural ecosystems, agroecosystems experience frequent disturbances, simplified vegetation structure, and high external energy inputs, which shape species composition and ecological processes (Gliessman, 2015). Despite these constraints, they support considerable biodiversity and provide essential ecosystem services such as nutrient cycling, pollination, soil formation, and natural pest regulation (Daily, 1997; Power, 2010).

In agroecosystems, functional biodiversity - particularly the roles of predators, parasitoids, pollinators, and decomposers - supports productivity and ecological balance (Altieri, 1999; Swift *et al.*, 2004). However, agricultural intensification has significantly contributed to biodiversity loss, especially among arthropods (Matson *et al.*, 1997; Benton *et al.*, 2003). As the most diverse animal group, arthropods occupy multiple trophic levels and perform essential ecological functions, acting both as pests and beneficial organisms. Their diversity and balance are strongly influenced by habitat complexity and management practices, making them key indicators of agroecosystem health (Andow, 1991; Pedigo *et al.*, 2021).



INDIA KERALA STUDY SITE

Fig. 1. Map showing the study site.

Among arthropods, spiders (Order Araneae) are one of the most diverse and ecologically significant groups of terrestrial predators, widely distributed across natural and agricultural systems (Wise, 1993; Nyffeler & Sunderland, 2003). They employ diverse hunting strategies such as web-building, ambushing, and active hunting, enabling efficient exploitation of prey (Uetz *et al.*, 1999; Cardoso *et al.*, 2011). Additionally, their advanced sensory and behavioural adaptations enhance predatory efficiency in agroecosystems (Barth, 2002).

Ecologically, spiders serve as effective generalist predators, regulating populations of major agricultural pests including aphids, leafhoppers, and caterpillars (Nyffeler *et al.*, 1994; Sunderland, 1999). Their continuous presence across crop growth stages ensures sustained pest suppression, making them important components of integrated pest management strategies (Marc *et al.*, 1999). Beyond pest control, spiders contribute to trophic dynamics and act as indicators of habitat quality and ecological integrity (Cardoso *et al.*, 2011; Dhanya *et al.*, 2022). Therefore, this study aims in conserving and documenting spider diversity in agroecosystems, which is essential for enhancing ecosystem services and promoting sustainable agriculture.

Material and Methods

The site selected for the study is a rice ecosystem which is located at Thirumittacode, Palakkad District, Kerala (Fig. 1). It is located 10.76808 North longitude and 76.188602 East latitude with an area of 64 cent (0.64 acres). The average altitude of collecting area is about 40 metres above the mean sea level. This is a warm, humid region and seasonal variation in temperatures ranges from 24°C to 35°C. Humidity is also showing seasonal fluctuation and is about 75% to 85%.

Collecting and observation of spiders were done during the period of 5 months from September 2025 to January 2026. Eight samples were collected from the study regions. The collection time was from 8.00 am to 10.00 am in the morning. For collecting purpose the study area was thoroughly searched for any potential spiders. The spider fauna from study sites was sampled using the line transect approach. There were a total of 2 Line transects placed throughout the selected habitats, each measuring 100 metres in length, 1 metres in width, and 2 metres in height. Throughout the 100 metre transects, which were sampled for 1-3 hours, spiders were gathered. To prevent the edge effect, transects were placed 20 metres inside the boundary. Spiders were gathered using a variety of methods, including vegetation beating, ground hand collecting, aerial hand collecting and litter sampling and standardized sampling procedures for collecting spiders are used.

Spiders that were trapped were kept separately in bottles of 80% ethyl alcohol. For the purpose of taxonomic identification, preserved specimens were studied in the lab using a stereo zoom microscope (Leica-MS5). With the aid of the literature that was accessible, spiders were recognised down to the species level (Sebastian & Peter, 2009; World Spider Catalog, 2026; Caleb & Sankaran, 2026). Diversity indices like Shannon-Wiener index (H′), Simpson's diversity index (D), Evenness index (E) and Species richness index (d) were calculated using MS Office standard Excel 2013 programme. The spider guild classification was constructed habitat wise, based on the families collected during the study. Classification of guild in the current study was according to the results of Cardoso *et al.* (2011).

Results

During the study period, a total of 290 individuals were collected. 64 species belonging to 48 genera from 14 families were listed from the collected individuals (Table 1). Out of the 14 families collected during the study, the family Salticidae was dominant family with 15 species belonging to 13 genera (Fig. 2). Family Thomisidae was the second dominant family with 9 species belonging to 7 genera. Family Tetragnathidae represents the third dominating family with 8 species belonging to 2 genera. The family Theridiidae was the fourth, with 6 species belonging to 4 genera. Family Araneidae was

the fifth dominant with 5 species and 4 genera. Families Pholcidae and Sparassidae were sixth dominant with 4 species belonging to 4 genera each. Families Lycosidae, Oxyopidae, and Uloboridae are the seventh dominating families with 3 species each belonging to 3, 1, and 2 genera respectively. The families Cheiracanthiidae, Corinnidae, Filistatidae, and Hersiliidae are least dominating with 1 species and 1 genus each (Table 2).

Table 1. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area.

NO.	FAMILY	Number of Genera	Number of Species
1	ARANEIDAE	4	5
2	CHEIRACANTHIIDAE	1	1
3	CORINNIDAE	1	1
4	FILISTATIDAE	1	1
5	HERSILIIDAE	1	1
6	LYCOSIDAE	3	3
7	OXYOPIDAE	1	3
8	PHOLCIDAE	4	4
9	SALTICIDAE	13	15
10	SPARASSIDAE	4	4
11	TETRAGNATHIDAE	2	8
12	THERIDIIDAE	4	6
13	THOMISIDAE	7	9
14	ULOBORIDAE	2	3
		48	64

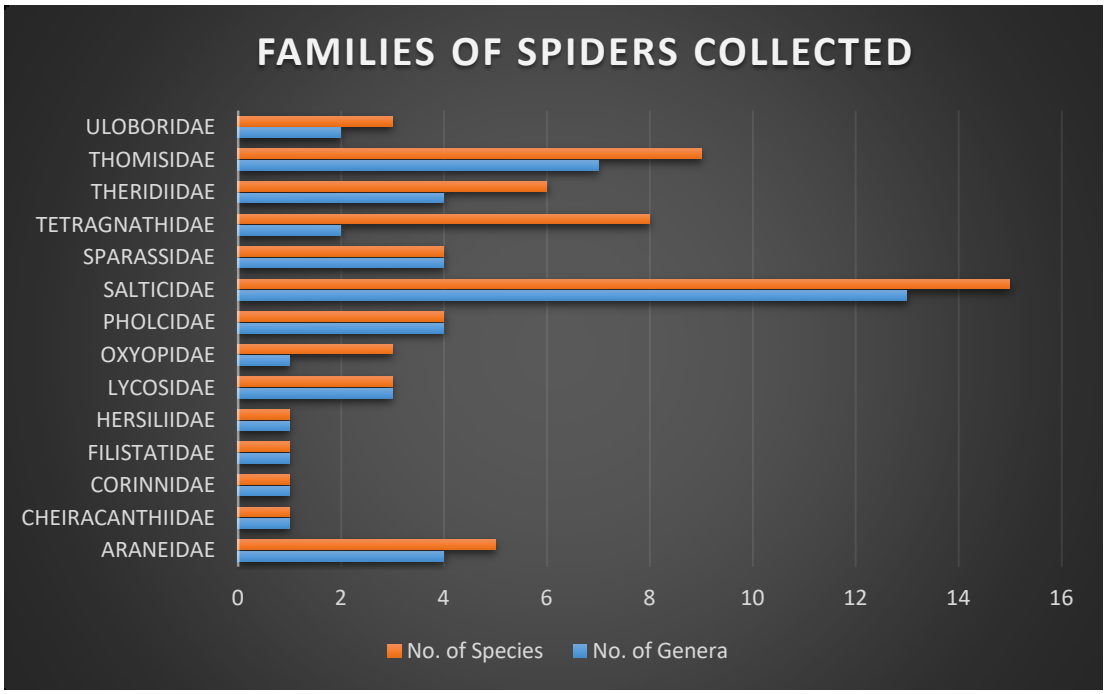


Fig. 2. Graph showing the distribution of genera and species in different spider families of the entire spider assemblage recorded in the study area.

Table 2. Checklist of spiders collected from entire study area.

NO.	Family / Genus / Species	Species Abundance
	1. ARANEIDAE	
1	*Argiope pulchella* Thorell, 1881	2
2	*Neoscona elliptica* Tikader & Bal, 1981	1
3	*Neoscona bengalensis* Tikader & Bal, 1981	2
4	*Neoscona mukerjei* Tikader, 1980	3
5	*Nephilengys malabarensis* (Walckenaer, 1841)	1
	2. CHEIRACANTHIIDAE	
6	*Cheiracanthium melanostoma* (Thorell, 1895)	1
	3. CORINNIDAE	
7	*Castianeira zetes* Simon, 1897	2
	4. FILISTATIDAE	
8	*Labahitha insularis* (Thorell, 1891)	4
	5. HERSILIIDAE	
9	*Hersilia savignyi* Lucas, 1836	2
	6. LYCOSIDAE	
10	*Draposa atropalpis* (Gravely, 1924)	5
11	*Hippasa agelenoides* (Simon, 1884)	17
12	*Pardosa sumatrana* (Thorell, 1890)	3
	7. OXYOPIDAE	
13	*Oxyopes hindostanicus* Pocock, 1901	2
14	*Oxyopes lineatipes* (C.L. Koch, 1847)	4
15	*Oxyopes shweta* Tikader, 1970	6
	8. PHOLCIDAE	
16	*Artema atlanta* Walckenaer, 1837	10
17	*Crossopriza lyoni* (Blackwall, 1867)	4
18	*Micropholcus fauroti* (Simon, 1887)	1
19	*Pribumia atrigularis* (Simon, 1901)	2
	9. SALTICIDAE	
20	*Carrhotus viduus* (C.L. Koch, 1846)	2
21	*Chalcotropis pennata* Simon, 1902	1
22	*Epocilla aurantiaca* (Simon, 1885)	3
23	*Hasarius adansoni* (Audouin, 1825)	7
24	*Hyllus semicupreus* (Simon, 1885)	10
25	*Menemerus bivittatus* (Dufour, 1831)	2
26	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	2
27	*Phintella vittata* (C.L. Koch, 1846)	1
28	*Plexippus paykulli* (Audouin, 1825)	11

29	*Plexippus petersi* (Karsch, 1878)	7
30	*Rhene flavigera* (C.L. Koch, 1846)	3
31	*Siler semiglaucus* (Simon, 1901)	2
32	*Stenaelurillus albus* Sebastian, Sankaran, Malamel & Joseph, 2015	9
33	*Stenaelurillus lesserti* Reimoser, 1934	2
34	*Telamonia dimidiata* (Simon, 1899)	6
	10. SPARASSIDAE	
35	*Heteropoda venatoria* (Linnaeus, 1767)	12
36	*Olios milleti* (Pocock, 1901)	2
37	*Pandercetes celatus* Pocock, 1899	9
38	*Thelcticopis kirankhalapi* Ahmed, Sumukha, Khalap, Mohan & Jadhav, 2015	7
	11. TETRAGNATHIDAE	
39	*Tetragnatha cochinensis* Gravely, 1921	1
40	*Tetragnatha javana* (Thorell, 1890)	2
41	*Tetragnatha keyserlingi* Simon, 1890	1
42	*Tetragnatha mandibulata* Walckenaer, 1841	10
43	*Tetragnatha squamata* Karsch, 1879	3
44	*Tetragnatha viridorufa* Gravely, 1921	5
45	*Tylorida striata* (Thorell, 1877)	12
46	*Tylorida ventralis* (Thorell, 1877)	12
	12. THERIDIIDAE	
47	*Argyrodes gazedes* Tikader, 1970	1
48	*Chrysso urbasae* (Tikader, 1970)	1
49	*Meotipa multuma* Murthappa, Malamel, Prajapati, Sebastian & Venkateshwarlu, 2017	2
50	*Meotipa picturata* Simon, 1895	3
51	*Nihonhimea mundula* (L. Koch, 1872)	5
52	*Physcoa angula* (Tikader, 1970)	2
	13. THOMISIDAE	
53	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)	1
54	*Camaricus formosus* Thorell, 1887	2
55	*Epidius parvati* Benjamin, 2000	1
56	*Indoxysticus minutus* (Tikader, 1960)	19
57	*Strigoplus netravati* Tikader, 1963	1
58	*Thomisus bulani* Tikader, 1960	1
59	*Thomisus projectus* Tikader, 1960	14
60	*Thomisus pugilis* Stoliczka, 1869	2
61	*Tmarus hystrix* (Simon, 1895)	1
	14. ULOBORIDAE	
62	*Hyptiotes indicus* Simon, 1905	1
63	*Uloborus khasiensis* Tikader, 1969	1
64	*Uloborus krishnae* Tikader, 1970	16

Spiders collected from the study area were classified into six guilds based on their feeding behaviour: (1) Ambush hunters (Thomisidae, Sparassidae, and Hersiliidae); (2) Ground hunters (Corinnidae and Lycosidae); (3) Orb web weavers (Araneidae, Tetragnathidae, and Uloboridae); (4) Space web builders (Pholcidae, Filistatidae, and Theridiidae); (5) Foliage hunters (Oxyopidae and Cheiracanthiidae), and (6) Stalkers (Salticidae). Results of spider species richness among guilds in the total study area shows that the guild of orb web weavers showed the highest species richness with 25% (16 species) followed by stalkers with 23.44% (15 species). There are remaining 21.88% of ambush hunters (14 species), 17.18% of space web builders (11 species) and 6.25% of ground hunters and foliage hunters (4 species each) (Figs. 3 & 4).

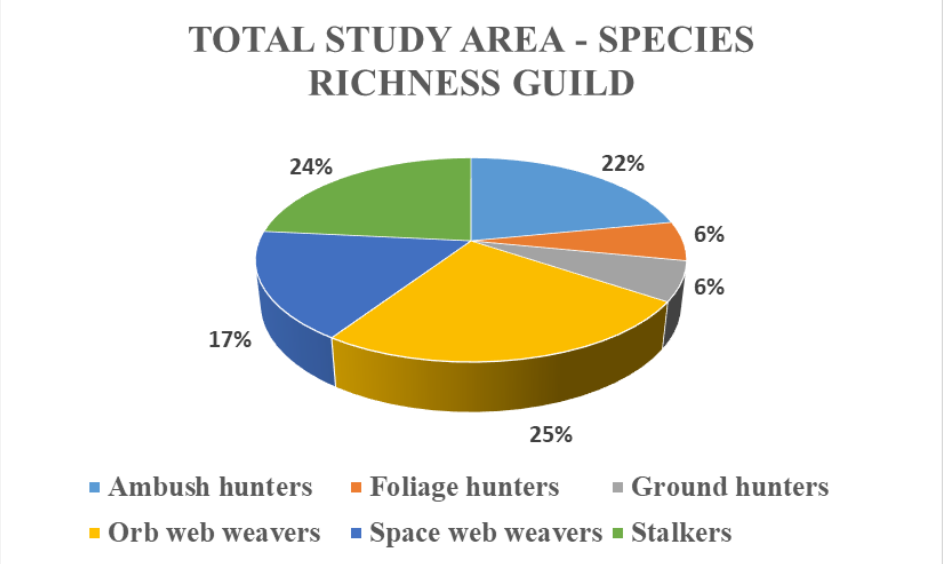


Fig. 3. Species richness of spiders in the guilds of total study area.

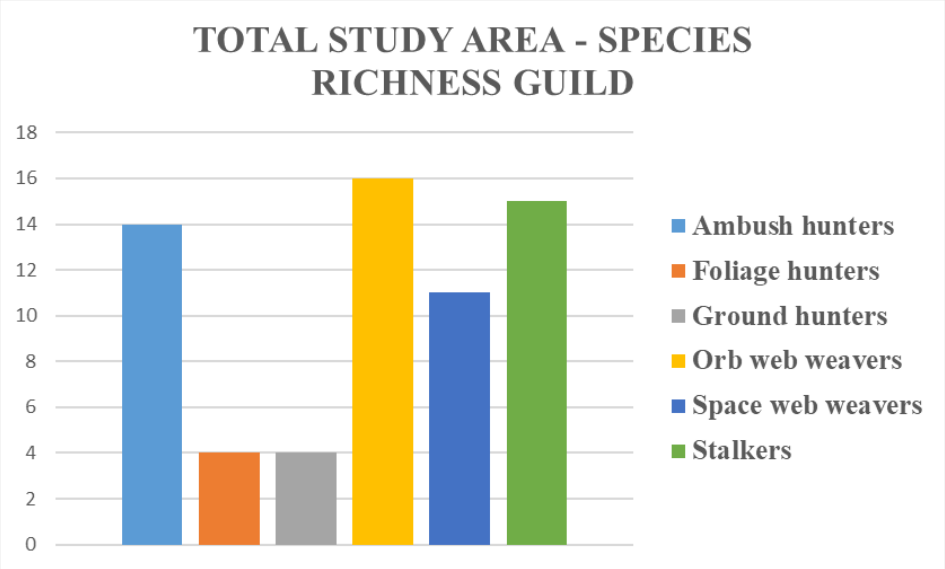


Fig. 4. Species richness of spiders in the guilds of the total study area.

Composition of species abundance in the guilds of total study area constitute 25.52% ambush hunters (74 individuals), 25.17% orb web weavers (73 individuals), 23.45% stalkers (68 individuals), 12.07% space web builders (35 individuals), 9.31%

ground hunters (27 individuals) and 4.48% foliage hunters (13 individuals). Highest abundance was shown by the guild of ambush hunters followed by orb web weavers and the least abundance was shown by foliage hunters (Figs. 5 & 6).

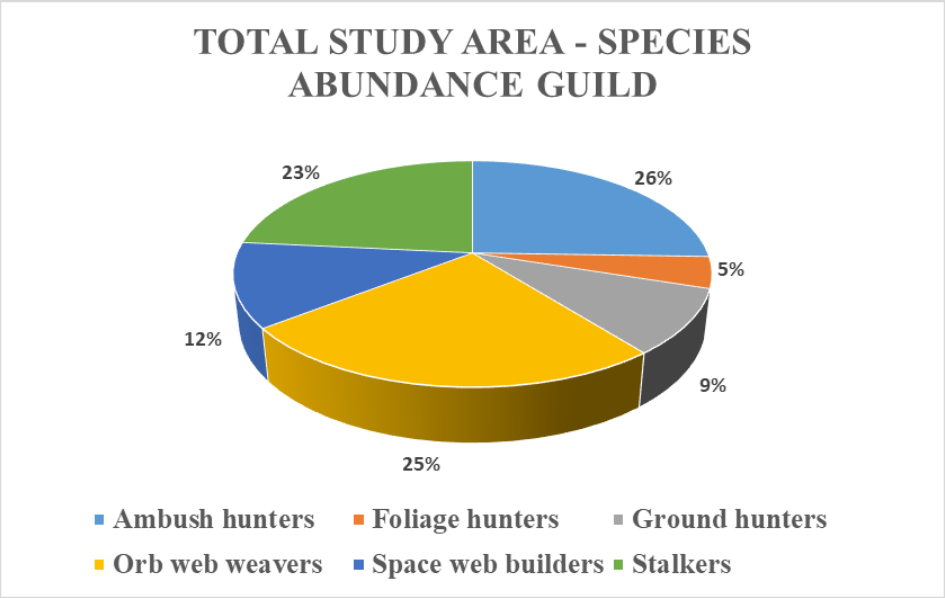


Fig. 5. Spider abundance among the guilds of total study area.

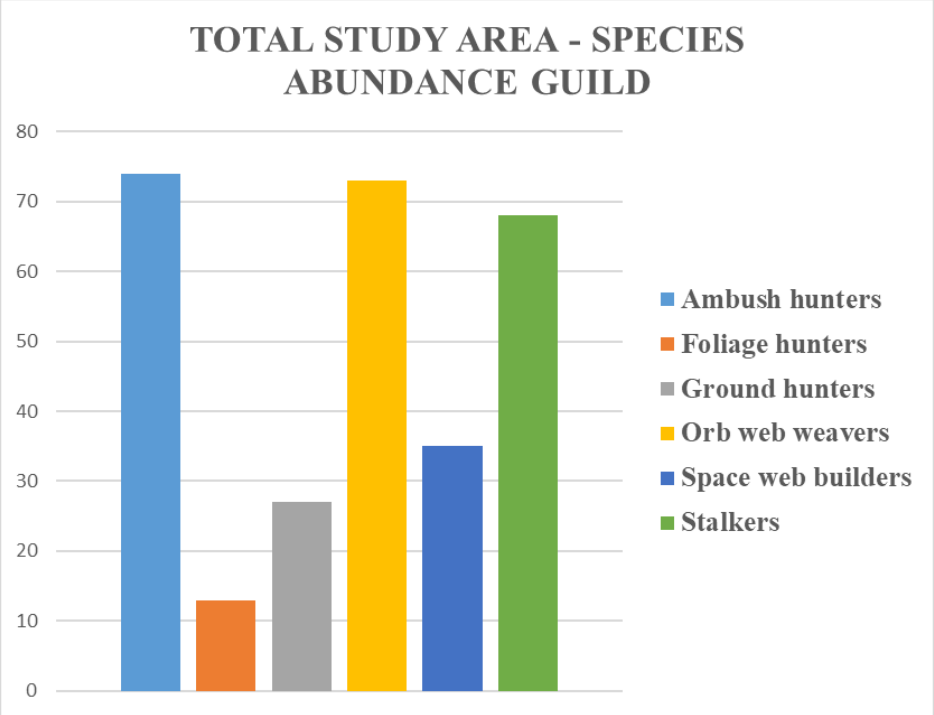


Fig. 6. Spider abundance among the guilds of the total study area.

Species richness was the same for total study area to have a value (0.2206) less than this for species richness. Total study area shown a value of 2.3337 for H' and 0.8933 for D. The evenness indicates uniform distribution of spiders in the study area. Here evenness is 0.8842 (Table 3).

Table 3. Diversity data on spiders of selected agroecosystem of Thirumittakode, Palakkad during the study period.

Study area	No. of species (S)	No. of individual (N)	Species richness (d)	Shannon-Wiener index (H')	Simpson index (D)	Evenness (E)
Total study area	64	290	0.2206	2.3337	0.8933	0.8842

Discussion

The current study is the first attempt to document the spider fauna of rice agroecosystems of Thirumittacode, Palakkad. During the study period, a total of 64 species from 48 genera in 14 families were collected from the total study area. The families Salticidae and Thomisidae were the most dominant of the 14 families studied, with 15 and 9 species belonging to 13 and 7 genera. There is a link between habitat structural complexity and species diversity, according to various studies (Andow, 1991). Uetz (1991), discovered that a more structurally complex shrub can host a more diversified spider community. The structure of vegetation plays a significant role in determining the dominance of these spider families in the study area. The distribution and occurrence of spiders are strongly influenced by habitat complexity and vegetational characteristics, and human activities that modify the ecosystem may lead to habitat degradation and even local extinction of certain species.

Highest species richness in the total study area was shown by the guild of orb web weavers followed by stalkers. The most abundant guild in the total study area was the guild of ambush hunters followed by orb web weavers. The typical orb web weavers (Araneidae, Uloboridae, and Tetragnathidae) are the most common group of spiral wheel-shaped web builders found in fields, gardens, and forests. Vegetation structure in the rice ecosystem may have influenced the spider composition and favoured the orb web weavers leading to their abundance in the rice ecosystem. Least abundance was shown by foliage hunters in the rice ecosystem.

The study area comparatively exhibited high spider diversity with rich species composition and well distributed guild structure due to habitat complexity, diverse vegetation and abundant prey availability. Spiders act as efficient biological control agents and reliable bio indicators of environmental changes. Their presence supports ecological balance and enhances the stability of agroecosystems. These findings emphasize the need for conserving spider diversity to promote sustainable agriculture and ecosystem stability.

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Preliminary study of spiders associated with the galls of *Ziziphus spina-christi* "Sidr trees" in Faifa Mountains, Jazan Province, Saudi Arabia

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Abstract

A total of 28 individuals of 8 families of spiders (Araneidae, Cheiracanthiidae, Gnaphosidae, Oxyopidae, Philodromidae, Salticidae, Theridiidae, and Thomisidae) were collected during January to April 2025, associated with the galls of Sidr trees in the Faifa Mountains of Saudi Arabia. The majority of individuals (22) are juvenile spiders in addition to 4 males and 2 females. The dominant family is Theridiidae with 7 individuals (2♂♂, 1♀, and 4 juv.), *i.e.* 25% of the collection. The theridiid species *Dipoenoides episinoides* and genus *Dipoenoides* are new records for the Kingdom of Saudi Arabia.

Keywords: Araneae, Theridiidae, *Dipoenoides episinoides*, Sidr, Galls, Saudi Arabia.

Introduction

While studying the galls of Sidr trees in the Faifa Mountains of Saudi Arabia, we found insects and spiders inside and on these galls. In this preliminary work, we present a list of spiders associated with these galls, especially since, despite their small number, some are recorded for the first time in Saudi Arabia, both at the genus and species level. Furthermore, all are recorded for the first time in the Jazan region.

Faifa Mountains (= Fayfa, Fifa) are located in the Jazan region of southwestern Saudi Arabia. These lush, pyramid-shaped mountains are known for their moderate temperatures, green terraced farms where coffee and maize are grown, and ancient

fortresses. The Faifa Mountains are a favoured spot for local tourism, offering stunning natural landscapes and ancient sites for visitors to explore (Wikipedia, 2026) (Figs. 1-2).

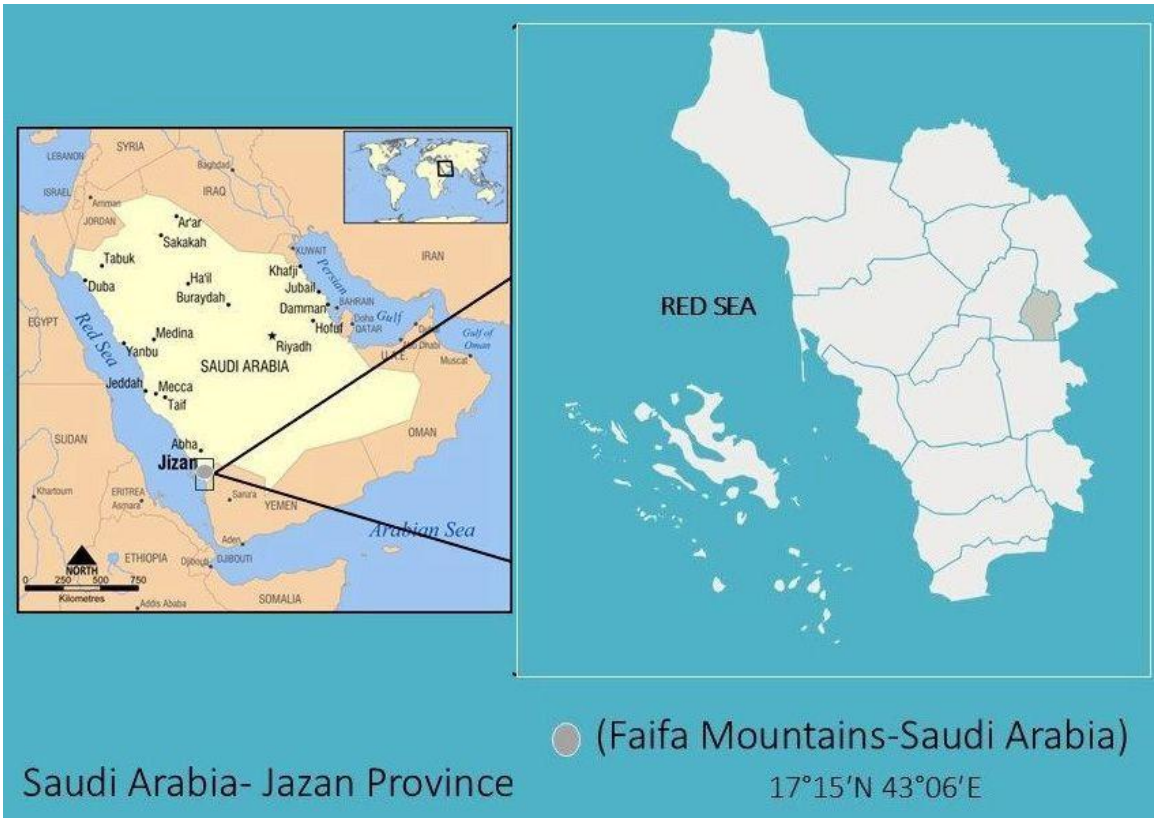

Fig. 1. Map of Jazan region and Faifa Mountains of southwestern Saudi Arabia.

Fig. 2. Clouds and plants on Faifa Mountains.

Material and Methods

Study area, Faifa

The Faifa mountains [17°15'21.3"N, 43°06'06.4"E] 1496 m a.s.l. (also spelled Fifa or Fayfa) are located in the vicinity of Faifa town east of Jizan in the Jazan Province, southwest of Saudi Arabia.

Host plant "Sidr trees"

Ziziphus spina-christi (L.) (Rhamnaceae), known as the Christ's thorn jujube, is a thorny and evergreen tree (Fig. 3). The trees of this species have plant galls (Fig. 4).

Fig. 3. *Ziziphus spina-christi* (L.) "Sidr trees" in Faifa, east of Jizan.

Fig. 4. *Ziziphus spina-christi* (L.) "Sidr trees" in Faifa, east of Jizan; plant galls.

Collecting and examination

Spiders found on or inside the plant galls were collected by hand 7 times during the months January to April 2025 and preserved in 75% ethanol. A stereomicroscope with a digital camera was used to examine and to photograph the Faifan spiders. The identification of the theridiid species *Dipoenoides episinoides* (Walckenaer, 1847) depended on Miller (1963), Levy & Amitai (1981), and Levy (1998) in addition to Nentwig *et al.* (2026).

Results and Discussion

The studied collection of spiders includes 28 individuals that belong to 8 families, 11 identified genera, and 2 identified species:

Family Araneidae, *Larinia* sp. 1♂; *Larinioides* sp. 2j
Family Cheiracanthiidae, *Cheiracanthium* sp. 1s♂, 2j
Family Gnaphosidae 2j
Family Oxyopidae, *Peucetia* sp. 1♀
Family Philodromidae, *Thanatus* sp. 1j
Family Salticidae, *Afraflacilla* sp. 1♂; *Thyene* sp. 6j
Family Theridiidae, *Dipoenoides episinoides* (Walckenaer, 1847) 1♂;
Rhomphaea ? sp. 1j; *Theridion spinitarse* O. Pickard-Cambridge, 1876 1♂, 1♀, 1j; *Theridion* sp. 2j
Family Thomisidae, *Thomisus* sp. 4j

The majority of individuals are juveniles (22j) in addition to 4♂♂ and 2♀♀. The dominant family is Theridiidae Sundevall, 1833 (Cob Web Spiders) with 7 individuals (2♂♂, 1♀, and 4j), *i.e.* 25% of the collection.

The eight families, and the eleven identified genera, are already recorded from the Kingdom of Saudi Arabia (El-Hennawy, 2014). Four genera and seven species of Family Theridiidae Sundevall, 1833 are recorded from Saudi Arabia: *Latrodectus dahli* Levi, 1959, *L. geometricus* C.L. Koch, 1841, *L. renivulvatus* Dahl, 1902, *L. tredecimguttatus* (Rossi, 1790), *Paidiscura dromedaria* (Simon, 1880), *Steatoda paykulliana* (Walckenaer, 1805), and *Theridion spinitarse* O. Pickard-Cambridge, 1876.

Theridion spinitarse O. Pickard-Cambridge, 1876 was collected from Wadi Karrar and studied by Knoflach *et al.* (2009) depending on female specimens. Adult male and female from Faifa are included in our studied collection (Fig. 4). This widens its range of distribution.

A B

Fig. 5. *Theridion spinitarse* O. Pickard-Cambridge, 1876. A-B. Habitus, dorsal view. A. male. B. female.

Genus *Rhomphaea* (?) L. Koch, 1872 is recorded for the first time from Saudi Arabia by only one juvenile specimen (Fig. 6). Adult specimens are required to confirm this record. This genus (39 species) has high and long abdomen and its part behind the spinnerets much longer than the rest, more or less oblique.

Fig. 6. *Rhomphaea* sp. 1j. Habitus, lateral view.

The theridiid species *Dipoenoides episinoides* (Walckenaer, 1847) and genus *Dipoenoides* Chamberlin, 1925 are new records for the Kingdom of Saudi Arabia (Fig. 7). *D. episinoides* was described in detail as *Theridion scriptum* by Pickard-Cambridge (1872: 283), *Euryopis quadrimaculata* by Pickard-Cambridge (1876: 569), *Euryopis acuminata* by Levy & Amitai (1981: 178, f. 1-10), and Levy (1998: 144, f. 265-274). There are 35 species of genus *Dipoenoides* known from the following countries and regions: Argentina (3), Bolivia (1), Brazil (4), Canada (4), Cape Verde (1), Caucasus (1), China (7), Colombia (2), Egypt (1), Europe (1), Georgia (1), Greece (1), India (3), Iran (2), Jamaica (2), Japan (2), Mediterranean (1), Mexico (5), New Guinea? (1), Pakistan (2), Palestine (1), Panama (1), Peru (1), Reunion (1), South Africa (2), Sri Lanka (1), Turkey (1), Turkmenistan (1), and USA (17). The majority of species were recorded from USA (17) followed by China (7) then Mexico (5), Brazil (4), and Canada (4).

Dipoenoides episinoides is recorded from: Albania, Algeria, Belgium, Bulgaria, Cape Verde, China, Croatia, Cyprus, Czechia, Egypt, France, Georgia, Greece, India, Italy, Malta, Mediterranean, Montenegro, Morocco, Macedonia, Palestine, Portugal, Reunion, South Africa, Spain, Tunisia, and Türkiye (World Spider Catalog, 2026; Nentwig *et al.*, 2026).

In recent studies (Abu El-Ghiet *et al.*, 2025 and Alfaifi *et al.*, 2026), crimson galls on *Ziziphus spina-christi* in the Faifa Mountains accommodate moths (Lepidoptera: Pyralidae), *Drosophila* sp. (Diptera), mealybugs such as *Paracoccus marginatus* Williams & Granara de Willink, 1992 and *Pseudococcus viburni* Signoret, 1875 (Hemiptera), in addition to parasitoid wasps *Dolichogenidea faifaiensis* Edmardash & Gadallah, 2025 (Braconidae), *Temelucha minuta* (Morley, 1912) and *Trathala jazanica* Gadallah & Edmardash, 2025 (Ichneumonidae) and ants such as *Tetramorium* sp. (Formicidae). "All of those organisms contribute to the creation of complex ecological interactions. These findings highlight the ecological complexity within plant galls and emphasize the need for further studies on their internal interactions."

A

B

C

Fig. 7. *Dipoenoides episinoides* (Walckenaer, 1847) male. A. habitus, dorsal view. B-C. Pedipalp. B. retrolateral view. C. prolateral view.

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